ADVERTISEMENT.

The Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions*, take this opportunity to acquaint the Public, that it fully appears, as well from the Council-books and Journals of the Society, as from repeated declarations which have been made in several former *Transactions*, that the printing of them was always, from time to time, the single act of the respective Secretaries till the Forty-seventh Volume; the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March 1752. And the grounds of their choice are, and will continue to be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgement of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body, upon any subject, either of Nature or Art, that comes before them And therefore the thanks, which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they received them, are to be considered in no other light than as a matter of civility, in return for the respect shown to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report and even to certify in the public newspapers, that they have met with the highest applause and approbation. And therefore it is hoped that no regard will hereafter be paid to such reports and public notices; which in some instances have been too lightly credited, to the dishonour of the Society.

The Meteorological Journal hitherto kept by the Assistant Secretary at the Apartments of the Royal Society, by order of the President and Council, and published in the Philosophical Transactions, has been discontinued. The Government, on the recommendation of the President and Council, has established at the Royal Observatory at Greenwich, under the superintendence of the Astronomer Royal, a Magnetical and Meteorological Observatory, where observations are made on an extended scale, which are regularly published. These, which correspond with the grand scheme of observations now carrying out in different parts of the globe, supersede the necessity of a continuance of the observations made at the Apartments of the Royal Society, which could not be rendered so perfect as was desirable, on account of the imperfections of the locality and the multiplied duties of the observer.

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PHILOSOPHICAL TRANSACTIONS.

I. *Experimental Researches in Electricity.—Nineteenth Series.*

By Michael Faraday, *Esq., D.C.L. F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Cor. Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Gottingen, Modena, Stockholm, &c. &c.*

Received November 6,—Read November 20, 1845.

§ 26. *On the magnetization of light and the illumination of magnetic lines of force**.

¶ i. *Action of magnets on light.* ¶ ii. *Action of electric currents on light.* ¶ iii. *General considerations.*

¶ i. *Action of magnets on light.*

2146. I HAVE long held an opinion, almost amounting to conviction, in common I believe with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have one common origin ; or, in other words, are so directly related and mutually dependent, that they are convertible, as it were, one into another, and possess equivalents of power in their action*. In modern times the proofs of their convertibility have been accumulated to a very considerable extent, and a commencement made of the determination of their equivalent forces.

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* The title of this paper has, I understand, led many to a misapprehension of its contents, and I therefore take the liberty of appending this explanatory note. Neither accepting nor rejecting the hypothesis of an ether, or the corpuscular, or any other view that may be entertained of the nature of light; and, as far as I can see, nothing being really known of a ray of light more than of a line of magnetic or electric force, or even of a line of gravitating force, except as it and they are manifest in and by substances; I believe that, in the experiments I describe in the paper, light has been magnetically affected, *i. e.* that that which is magnetic in the forces of matter has been affected, and in turn has affected that which is truly magnetic in the force of light: by the term magnetic I include here either of the peculiar exertions of the power of a magnet, whether it be that which is manifest in the magnetic or the diamagnetic class of bodies. The phrase " illumination of the lines of magnetic force" has been understood to imply that I had rendered them luminous. This was not within my thought. I intended to express that the line of magnetic force was illuminated as the earth is illuminated by the sun, or the spider's web illuminated by the astronomer's lamp. Employing a ray of light, we can tell, *by the eye*, the direction of the magnetic lines through a body; and by the alteration of the ray and its optical effect on the eye, can see the course of the lines just as we can see the course of a thread of glass, or any other transparent substance, rendered visible by the light. and this was what I meant by *illumination*, as the paper fully explains.—December 15, 1845. M. F.

2147. This strong persuasion extended to the powers of light, and led, on a former occasion, to many exertions, having for their object the discovery of the direct relation of light and electricity, and their mutual action in bodies subject jointly to their power†; but the results were negative and were afterwards confirmed, in that respect, by WARTMANN‡.

2148. These ineffectual exertions, and many others which were never published, could not remove my strong persuasion derived from philosophical considerations; and, therefore, I recently resumed the inquiry by experiment in a most strict and searching manner, and have at last succeeded in *magnetizing and electrifying a ray of light, and in illuminating a magnetic line of force.* These results, without entering into the detail of many unproductive experiments, I will describe as briefly and clearly as I can.

2149. But before I proceed to them, I will define the meaning I connect with certain terms which I shall have occasion to use:—thus, by *line of magnetic force*, or *magnetic line of force,* or *magnetic curve,* I mean that exercise of magnetic force which is exerted in the lines usually called magnetic curves, and which equally exist as passing from or to magnetic poles, or forming concentric circles round an electric current. By *line of electric force,* I mean the force exerted in the lines joining two bodies, acting on each other according to the principles of static electric induction (1161, &c.), which may also be either in curved or straight lines. By a *diamagnetic,* I mean a body through which lines of magnetic force are passing, and which does not by their action assume the usual magnetic state of iron or loadstone.

2150. A ray of light issuing from an Argand lamp, was polarized in a horizontal plane by reflection from a surface of glass, and the polarized ray passed through a NICHOL's eye-piece revolving on a horizontal axis, so as to be easily examined by the latter. Between the polarizing mirror and the eye-piece, two powerful electro-magnetic poles were arranged, being either the poles of a horse-shoe magnet, or the contrary poles of two cylinder magnets; they were separated from each other about two inches in the direction of the line of the ray, and so placed, that, if on the same side of the polarized ray, it might pass near them; or, if on contrary sides, it might go between them, its direction being always parallel, or nearly so, to the magnetic lines of force (2149.). After that, any transparent substance placed between the two poles, would have passing through it, both the polarized ray and the magnetic lines of force at the same time and in the same direction.

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* Experimental Researches, 57, 366, 376, 877, 961, 2071.

† Philosophical Transactions, 1834. Experimental Researches, 951–955.

‡ Archives de l'Electricité, ii. pp. 596–600.

2151. Sixteen years ago I published certain experiments made upon optical glass*, and described the formation and general characters of one variety of heavy glass, which, from its materials, was called silicated borate of lead. It was this glass which first gave me the discovery of the relation between light and magnetism, and it has power to illustrate it in a degree beyond that of any other body; for the sake of perspicuity I will first describe the phenomena as presented by this substance.

2152. A piece of this glass, about two inches square and 0·5 of an inch thick, having flat and polished edges, was placed as a *diamagnetic* (2149.) between the poles (not as yet magnetized by the electric current), so that the polarized ray should pass through its length ; the glass acted as air, water, or any other indifferent substance would do; and if the eye-piece were previously turned into such a position that the polarized ray was extinguished, or rather the image produced by it rendered invisible, then the introduction of this glass made no alteration in that respect. In this state of circumstances the force of the electro-magnet was developed, by sending an electric current through its coils, and immediately the image of the lamp-flame became visible, and continued so as long as the arrangement continued magnetic. On stopping the electric current, and so causing the magnetic force to cease, the light instantly disappeared; these phenomena could be renewed at pleasure, at any instant of time, and upon any occasion, showing a perfect dependence of cause and effect.

2153. The voltaic current which I used upon this occasion, was that of five pair of GROVE's construction, and the electro-magnets were of such power that the poles would singly sustain a weight of from twenty-eight to fifty-six, or more, pounds. A person looking for the phenomenon for the first time would not be able to see it with a weak magnet.

2154. The character of the force thus impressed upon the diamagnetic is that of *rotation*; for when the image of the lamp-flame has thus been rendered visible, revolution of the eye-piece to the right or left, more or less, will cause its extinction ; and the further motion of the eye-piece to the one side or other of this position will produce the reappearance of the light, and that with complementary tints, according as this further motion is to the right- or left-hand.

2155. When the pole nearest to the observer was a marked pole, *i. e.* the same as the north end of a magnetic needle, and the further pole was unmarked, the rotation of the ray was right-handed; for the eye-piece had to be turned to the right-hand, or clock fashion, to overtake the ray and restore the image to its first condition. When the poles were reversed, which was instantly done by changing the direction of the electric current, the rotation was changed also and became left-handed, the alteration being to an equal degree in extent as before. The direction was always the same for the same *line of magnetic force* (2149.).

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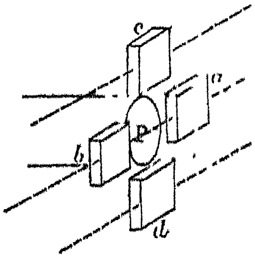
* Philosophical Transactions, 1830, p. 1. I cannot resist the occasion which is thus offered to me of mentioning the name of Mr. ANDERSON, who came to me as an assistant in the glass experiments, and has remained ever since in the Laboratory of the Royal Institution. He has assisted me in all the researches into which I have entered since that time, and to his care, steadiness, exactitude, and faithfulness in the performance of all that has been committed to his charge, I am much indebted.—M. F.

2156. When the diamagnetic was placed in the numerous other positions, which can easily be conceived, about the magnetic poles, results were obtained more or less marked in extent, and very definite in character, but of which the phenomena just described may be considered as the chief example: they will be referred to, as far as is necessary, hereafter.

2157. The same phenomena were produced in the silicated borate of lead (2151.) by the action of a good ordinary steel horse-shoe magnet, no electric current being now used. The results were feeble, but still sufficient to show the perfect identity of action between electro-magnets and common magnets in this their power over light.

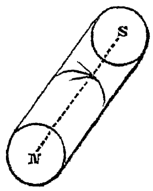
2158. Two magnetic poles were employed end-ways, *i. e.* the cores of the electro-magnets were hollow iron cylinders, and the ray of polarized light passed along their axes and through the diamagnetic placed between them: the effect was the same.

2159. One magnetic pole only was used, that being one end of a powerful cylinder electro-magnet. When the heavy glass was beyond the magnet, being close to it but between the magnet and the polarizing reflector, the rotation was in one direction, dependent on the nature of the pole; when the diamagnetic was on the near side, being close to it but between it and the eye, the rotation for the same pole was in the contrary direction to what it was before; and when the magnetic pole was changed, both these directions were changed with it. When the heavy glass was placed in a corresponding position to the pole, but above or below it, so that the *magnetic curves* were no longer passing through the glass parallel to the ray of polarized light, but rather perpendicular to it, then no effect was produced. These particularities may be understood by reference to fig. 1, where *a* and *b* represent the first positions of the diamagnetic, and *c* and *d* the latter positions, the course of the ray being marked by the dotted line. If also the glass were placed directly at the end of the magnet, then no effect was produced on a ray passing in the direction here described, though it is evident, from what has been already said (2155.), that a ray passing *parallel* to the magnetic lines through the glass so placed, would have been affected by it.



2160. Magnetic lines, then, in passing through silicated borate of lead, and a great number of other substances (2173.), cause these bodies to act upon a polarized ray of light when the lines are parallel to the ray, or in proportion as they are parallel to ; if they are perpendicular to the ray, they have no action upon it. They give the amagnetic the power of rotating the ray; and the *law* of this action on light is, that a magnetic line of force be *going from* a north pole, or *coming* from a south pole, long the path of a polarized ray coming to the observer, it will rotate that ray to e right-hand; or, that if such a line of force be coming from a north pole, or going om a south pole, it will rotate such a ray to the left-hand.

2161. If a cork or a cylinder of glass, representing the diamagnetic, be marked at its ends with the letters N and S, to represent the poles of a magnet, the line joining these letters may be considered as a magnetic line of force; and further, if a line be traced round the cylinder with arrow heads on it to represent direction, as in the figure, such a simple model, held up before the eye, will express the whole of the law, and give every position and consequence of direction resulting from it. If a watch be considered as the diamagnetic, the north pole of a magnet being imagined against the face, and a south pole against the back, then the motion of the hands will indicate the direction of rotation which a ray of light undergoes by magnetization.



2162. I will now proceed to the different circumstances which affect, limit, and define the extent and nature of this new power of action on light.

2163. In the first place, the rotation appears to be in proportion to the extent of the diamagnetic through which the ray and the magnetic lines pass. I preserved the strength of the magnet and the interval between its poles constant, and then interposed different pieces of the same heavy glass (2151.) between the poles. The greater the extent of the diamagnetic in the line of the ray, whether in one, two, or three pieces, the greater was the rotation of the ray; and, as far as I could judge by these first experiments, the amount of rotation was exactly proportionate to the extent of diamagnetic through which the ray passed. No addition or diminution of the heavy glass on the *side* of the course of the ray made any difference in the effect of that part through which the ray passed.

2164. The power of rotating the ray of light *increased* with the intensity of the magnetic lines of force. This general effect is very easily ascertained by the use of electro-magnets; and within such range of power as I have employed, it appears to be directly proportionate to the intensity of the magnetic force.

2165. Other bodies, besides the heavy glass, possess the same power of becoming, under the influence of magnetic force, active on light (2173.). When these bodies possess a rotative power of their own, as is the case with oil of turpentine, sugar, tartaric acid, tartrates, &c., the effect of the magnetic force is to add to, or subtract from, their specific force, according as the natural rotation and that induced by the magnetism is right or left-handed (2231.).

2166. I could not perceive that this power was affected by any degree of motion which I was able to communicate to the diamagnetic, whilst jointly subject to the action of the magnetism and the light.

2167. The interposition of copper, lead, tin, silver, and other ordinary non-magnetic bodies in the course of the magnetic curves, either between the pole and the diamagnetic, or in other positions, produced no effect either in kind or degree upon the phenomena.

2168. Iron frequently affected the results in a very considerable degree; but it always appeared to be, either by altering the direction of the magnetic lines, or disposing within itself of their force. Thus, when the two contrary poles were on one side of the polarized ray (2150.), and the heavy glass in its best position between them and in the ray (2152.), the bringing of a large piece of iron near to the glass on the other side of the ray, caused the power of the diamagnetic to fall. This was because certain lines of magnetic force, which at first passed through the glass parallel to the ray, now crossed the glass and the ray; the iron giving two contrary poles opposite the poles of the magnet, and thus determining a new course for a certain portion of the magnetic power, and that across the polarized ray.

2169. Or, if the iron, instead of being applied on the opposite side of the glass, were applied on the same side with the magnet, either near it or in contact with it, then, again, the power of the diamagnetic fell, simply because the power of the magnet was diverted from it into a new direction. These effects depend much of course on the intensity and power of the magnet, and on the size and softness of the iron.

2170. The electro-helices (2190.) without the iron cores were very feeble in power, and indeed hardly sensible in their effect. With the iron cores they were powerful, though no more electricity was then passing through the coils than before (1071.). This shows, in a very simple manner, that the phenomena exhibited by light under these circumstances, is directly connected with the magnetic form of force supplied by the arrangement. Another effect which occurred illustrated the same point. When the contact at the voltaic battery is made, and the current sent round the electro-magnet, the image produced by the rotation of the polarized ray does not rise up to its full lustre immediately, but increases for a couple of seconds, gradually acquiring its greatest intensity; on breaking the contact, it sinks instantly and disappears apparently at once. The gradual rise in brightness is due to the *time* which the iron core of the magnet requires to evolve all that magnetic power which the electric current can develope in it; and as the magnetism rises in intensity, so does its effect on the light increase in power; hence the progressive condition of the rotation.

2171. I cannot as yet find that the heavy glass (2151.), when in this state, *i. e.* with magnetic lines of force passing through it, exhibits any increased degree, or has any specific magneto-inductive action of the recognized kind. I have placed it in large quantities, and in different positions, between magnets and magnetic needles, having at the time very delicate means of appreciating any difference between it and air, but could find none.

2172. Using water, alcohol, mercury, and other fluids contained in very large delicate thermometer-shaped vessels, I could not discover that any difference in volume occurred when the magnetic curves passed through them.

2173. It is time that I should pass to a consideration of this power of magnetism over light as exercised, not only in the silicated borate of lead (2151.), but in many other substances; and here we perceive, in the first place, that if all transparent bodies possess the power of exhibiting the action, they have it in very different degrees, and that up to this time there are some that have not shown it at all.

2174. Next, we may observe, that bodies that are exceedingly different to each other in chemical, physical, and mechanical properties, develope this effect; for solids and liquids, acids, alkalies, oils, water, alcohol, ether, all possess the power.

2175. And lastly, we may observe, that in all of them, though the degree of action may differ, still it is always the same in kind, being a rotative power over the ray of light; and further, the direction of the rotation is, in every case, independent of the nature or state of the substance, and dependent upon the direction of the magnetic line of force, according to the law before laid down (2160.).

2176. Amongst the substances in which this power of action is found, I have already distinguished the *silico-borate of lead* (2151.) as eminently fitted for the purpose of exhibiting the phenomena. I regret that it should be the best, since it is not likely to be in the possession of many, and few will be induced to take the trouble of preparing it. If made, it should be well annealed, for otherwise the pieces will have considerable power of depolarizing light, and then the particular phenomena under consideration are much less strikingly observed. The *borate of lead*, however, is a substance much more fusible, softening at the heat of boiling oil, and therefore far more easily prepared in the form of glass plates and annealed; and it possesses as much magneto-rotative power over light as the silico-borate itself. *Flint-glass* exhibits the property, but in a less degree than the substances above. Crown-glass shows it, but in a still smaller degree.

2177. Whilst employing crystalline bodies as diamagnetics, I generally gave them that position in which they did not affect the polarized ray, and then induced the magnetic curves through them. As a class, they seemed to resist the assumption of the rotating state. *Rock-salt* and *fluor-spar* gave evidence of the power in a slight degree; and I think that a crystal of alum did the same, but its ray length in the transparent part was so small that I could not ascertain the fact decisively. Two specimens of transparent fluor, lent me by Mr. TENNANT, gave the effect.

2178. Rock-crystal, four inches across, gave no indications of action on the ray, neither did smaller crystals, nor cubes about three-fourths of an inch in the side, which were so cut as to have two of their faces perpendicular to the axis of the crystal (1692, 1693.), though they were examined in every direction.

2179. *Iceland spar* exhibited no signs of effect, either in the form of rhomboids, or of cubes like those just described (1695.).

2180. *Sulphate of baryta, sulphate of lime,* and *carbonate of soda,* were also without action on the light.

2181. A piece of fine clear *ice* gave me no effect. I cannot however say there is none, for the effect of water in the same mass would be very small, and the irregularity of the flattened surface from the fusion of the ice and flow of water, made the observation very difficult.

2182. With some degree of curiosity and hope, I put gold-leaf into the magnetic lines, but could perceive no effect. Considering the extremely small dimensions of the length of the path of the polarized ray in it, any positive result was hardly to be expected.

2183. In experiments with liquids, a very good method of observing the effect, is to inclose them in bottles from 1½ to 3 or 4 inches in diameter, placing these in succession between the magnetic poles (2150.), and bringing the analysing eye-piece so near to the bottle, that, by adjustment of the latter, its cylindrical form may cause a diffuse but useful image of the lamp-flame to be seen through it: the light of this image is easily distinguished from that which passes by irregular refraction through the striæ and deformations of the glass, and the phenomena being looked for in this light are easily seen.

2184. Water, alcohol, and ether, all show the effect; water most, alcohol less, and ether the least. All the fixed oils which I have tried, including almond, castor, olive, poppy, linseed, sperm, elaine from hog's lard, and distilled resin oil, produce it. The essential oils of turpentine, bitter almonds, spike lavender, lavender, jessamine, cloves, and laurel, produce it. Also naphtha of various kinds, melted spermaceti, fused sulphur, chloride of sulphur, chloride of arsenic, and every other liquid substance which I had at hand and could submit in sufficient bulk to experiment.

2185. Of aqueous solutions I tried 150 or more, including the soluble acids, alkalies and salts, with sugar, gum, &c., the list of which would be too long to give here, since the great conclusion was, that the exceeding diversity of substance caused no exception to the general result, for all the bodies showed the property. It is indeed more than probable, that in all these cases the water and not the other substance present was the ruling matter. The same general result was obtained with alcoholic solutions.

2186. Proceeding from liquids to air and gaseous bodies, I have here to state that, as yet, I have not been able to detect the exercise of this power in any one of the substances in this class. I have tried the experiment with bottles 4 inches in diameter, and the following gases: oxygen, nitrogen, hydrogen, nitrous oxide, olefiant gas, sulphurous acid, muriatic acid, carbonic acid, carbonic oxide, ammonia, sulphuretted hydrogen, and bromine vapour, at ordinary temperatures; but they all gave negative results. With air, the trial has been carried, by another form of apparatus, to a much higher degree, but still ineffectually (2212.).

2187. Before dismissing the consideration of the substances which exhibited this power, and in reference to those in which it was superinduced upon bodies possessing, naturally, rotative force (2165. 2231.), I may record, that the following are the substances submitted to experiment: castor oil, resin oil, oil of spike lavender, of laurel, Canada balsam, alcoholic solution of camphor, alcoholic solution of camphor and corrosive sublimate, aqueous solutions of sugar, tartaric acid, tartrate of soda, tartrate of potash and antimony, tartaric and boracic acid, and sulphate of nickel, which rotated to the right-hand; copaiba balsam, which rotated the ray to the left-hand; and two specimens of camphine or oil of turpentine, in one of which the rotation was to the right-hand, and in the other to the left. In all these cases, as already said (2165.), the superinduced magnetic rotation was according to the general law (2160.), and without reference to the previous power of the body.

2188. Camphor being melted in a tube about an inch in diameter, exhibited high natural rotative force, but I could not discover that the magnetic curves induced additional force in it. It may be, however, that the shortness of the ray length and the quantity of coloured light left, even when the eye-piece was adjusted to the most favourable position for darkening the image produced by the naturally rotated ray, rendered the small magneto-power of the camphor insensible.

¶ ii. *Action of electric currents on light.*

2189. From a consideration of the nature and position of the lines of magnetic and electric force, and the relation of a magnet to a current of electricity, it appeared almost certain that an electric current would give the same result of action on light as a magnet; and, in the helix, would supply a form of apparatus in which great lengths of diamagnetics, and especially of such bodies as appeared to be but little affected between the poles of the magnet, might be submitted to examination and their effect exalted: this expectation was, by experiment, realized.

2190. Helices of copper wire were employed, three of which I will refer to. The first, or *long helix*, was 0·4 of an inch internal diameter; the wire was 0·03 of an inch in diameter, and having gone round the axis from one end of the helix to the other, then returned in the same manner, forming a coil sixty-five inches long, double in its whole extent, and containing 1240 feet of wire.

2191. The second, or *medium helix*, is nineteen inches long, 1·87 inch internal diameter, and three inches external diameter. The wire is 0·2 of an inch in diameter, and eighty feet in length, being disposed in the coil as two concentric spirals. The electric current, in passing through it, is not divided, but traverses the whole length of the wire.

2192. The third, or *Woolwich helix*, was made under my instruction for the use of Lieut.-Colonel SABINE's establishment at Woolwich. It is 26·5 inches long, 2·5 inches internal diameter, and 4·75 inches external diameter. The wire is 0·17 of an inch in diameter, and 501 feet in length. It is disposed in the coil in four concentric spirals connected end to end, so that the whole of the electric current employed passes through all the wire.

2193. The long helix (2190.) acted very feebly on a magnetic needle placed at a little distance from it; the medium helix (2191.) acted more powerfully, and the Woolwich helix (2192.) very strongly; the same battery of ten pairs of GROVE's plate being employed in all cases.

2194. Solid bodies were easily subjected to the action of these electro-helices, being for that purpose merely cut into the form of bars or prisms with flat and ends, and then introduced as cores into the helices. For the purpose of submitting liquid bodies to the same action, tubes of glass were provided, furnished at the ends with caps; the cylindrical part of the cap was brass, and had a tubular aperture for the introduction of the liquids, but the end was a flat glass plate. When the tube was intended to contain aqueous fluids, the plates were attached to the caps, and the caps to the tube by Canada balsam; when the tube had to contain alcohol, ether or essential oils, a thick mixture of powdered gum with a little water was employed as the cement.

2195. The general effect produced by this form of apparatus may be stated as follows:—The tube within the long helix (2190.) was filled with distilled water and placed in the line of the polarized ray, so that by examination through the eye-piece (2150.), the image of the lamp-flame produced by the ray could be seen through it. Then the eye-piece was turned until the image of the flame disappeared, and, afterwards, the current of ten pairs of plates sent through the helix; instantly the image of the flame reappeared, and continued as long as the electric current was passing through the helix; on stopping the current the image disappeared. The light did not rise up gradually, as in the case of electro-magnets (2170.), but instantly. These results could be produced at pleasure. In this experiment we may, I think, justly say that a ray of light is electrified and the electric forces illuminated.

2196. The phenomena may be made more striking, by the adjustment of a lens of long focus between the tube and the polarizing mirror, or one of short focus between the tube and the eye; and where the helix, or the battery, or the substance experimented with, is feeble in power, such means offer assistance in working out the effects: but, after a little experience, they are easily dispensed with, and are only useful as accessories in doubtful cases.

2197. In cases where the effect is feeble, it is more easily perceived if the Nichol eye-piece be adjusted, not to the perfect extinction of the ray, but a little short of or beyond that position; so that the image of the flame may be but just visible. Then, on the exertion of the power of the electric current, the light is either increased in intensity, or else diminished, or extinguished, or even re-illuminated on the other side of the dark condition; and this change is more easily perceived than if the eye began to observe from a state of utter darkness. Such a mode of observing also assists in demonstrating the rotatory character of the action on light; for, if the light be made visible beforehand by the motion of the eye-piece in one direction, and the power of the current be to *increase* that light, an instant only suffices, after stopping the current, to move the eye-piece in the other direction until the light is apparent as at first, and then the power of the current will be to *diminish* it; the tints of the lights being affected also at the same time.

2198. When the current was sent round the helix in one direction, the rotation induced upon the ray of light was one way; and when the current was changed to the contrary direction, the rotation was the other way. In order to express the direcion, I will assume, as is usually done, that the current passes from the zinc through he acid to the platinum in the same cell (663. 667. 1627.): if such a current pass nder the ray towards the right, upwards on its right side, and over the ray towards he left, it will give left-handed rotation to it; or, if the current pass over the ray to he right, down on the right side, and under it towards the left, it will induce it to otate to the right-hand.

2199. The LAW, therefore, by which an electric current acts on a ray of light is asily expressed. When an electric current passes round a ray of polarized light in plane perpendicular to the ray, it causes the ray to revolve on its axis, as long as t is under the influence of the current, in the *same direction* as that in which the urrent is passing.

2200. The simplicity of this law, and its identity with that given before, as expressing the action of magnetism on light (2160.), is very beautiful. A model is not wanted to assist the memory; but if that already described (2161.) be looked at, the line round it will express at the same time the direction both of the current and the rotation. It will indeed do much more; for if the cylinder be considered as a piece of iron, and not a piece of glass or other diamagnetic, placed between the two poles N and S, then the line round it will represent the direction of the currents, which, according to AMPÈRE's theory, are moving round its particles; or if it be considered as a core of iron (in place of a core of water), having an electric current running round it in the direction of the line, it will also represent such a magnet as would be formed if it were placed between the poles whose marks are affixed to its ends.

2201. I will now notice certain points respecting the degree of this action under different circumstances. By using a tube of water (2194.) as long as the helix, but placing it so that more or less of the tube projected at either end of the helix, I was able, in some degree, to ascertain the effect of length of the diamagnetic, the force of the helix and current remaining the same. The greater the column of water subjected to the action of the helix, the greater was the rotation of the polarized ray; and the amount of rotation seemed to be directly proportionate to the length of fluid round which the electric current passed.

2202. A short tube of water, or a piece of heavy glass, being placed in the axis of the Woolwich helix (2192.), seemed to produce equal effect on the ray of light, whether it were in the middle of the helix or at either end; provided it was always within the helix and in the line of the axis. From this it would appear that every part of the helix has the same effect; and, that by using long helices, substances may be submitted to this kind of examination which could not be placed in sufficient length between the poles of magnets (2150.).

2203. A tube of water as long as the Woolwich helix (2192.), but only 0·4 of an inch in diameter, was placed in the helix parallel to the axis, but sometimes in the axis and sometimes near the side. No apparent difference was produced in these different situations; and I am inclined to believe (without being quite sure) that the action on the ray is the same, wherever the tube is placed, within the helix, in relation to the axis. The same result was obtained when a larger tube of water was looked through, whether the ray passed through the axis of the helix and tube, or near the side.

2204. If bodies be introduced into the helix possessing, naturally, rotating force, then the rotating power given by the electric current is superinduced upon them, exactly as in the cases already described of magnetic action (2165. 2187.).

2205. A helix, twenty inches long and 0·3 of an inch in diameter, was made of uncovered copper wire, 0·05 of an inch in diameter, in close spirals. This was placed in a large tube of water, so that the fluid, both in the inside and at the outside of the helix, could be examined by the polarized ray. When the current was sent *through* the helix, the water within it received rotating power; but no trace of such an action on the light was seen on the outside of the helix, even in the line most close to the uncovered wire.

2206. The water was inclosed in brass and copper tubes, but this alteration caused not the slightest change in the effect.

2207. The water in the brass tube was put into an *iron* tube, much longer than either the Woolwich helix or the brass tube, and quite one eighth of an inch thick in the side; yet when placed in the Woolwich helix (2192.), the water rotated the ray of light apparently as well as before.

2208. An iron bar, one inch square and longer than the helix, was put into the helix, and the small water tube (2203.) upon it. The water exerted as much action on the light as before.

2209. Three iron tubes, each twenty-seven inches long and one-eighth of an inch in thickness in the side, were selected of such diameters as to pass easily one into the other, and the whole into the Woolwich helix (2192.). The smaller one was supplied with glass ends and filled with water; and being placed in the axis of the Woolwich helix, had a certain amount of rotating power over the polarized ray. The second tube was then placed over this, so that there was now a thickness of iron equal to two-eighths of an inch between the water and the helix; the water had *more* power of rotation than before. On placing the third tube of iron over the two former, the power of the water *fell*, but was still very considerable. These results are complicated, being dependent on the new condition which the character of iron gives to its action on the forces. Up to a certain amount, by increasing the development of magnetic forces, the helix and core, *as a whole*, produce increased action on the water; but on the addition of more iron and the disposal of the forces through it, their action is removed in part from the water and the rotation is lessened.

2210. Pieces of heavy glass (2151.), placed in iron tubes in the helices, produced similar effects.

2211. The bodies which were submitted to the action of an electric current in a helix, in the manner already described, were as follows:—Heavy glass (2151. 2176.), water, solution of sulphate of soda, solution of tartaric acid, alcohol, ether, and oil of turpentine; all of which were affected, and acted on light exactly in the manner described in relation to magnetic action (2173.).

2212. I submitted *air* to the influence of these helices carefully and anxiously, but could not discover any trace of action on the polarized ray of light. I put the long helix (2190.) into the other two (2191. 2192.), and combined them all into one consistent series, so as to accumulate power, but could not observe any effect of them on light passing through air.

2213. In the use of helices, it is necessary to be aware of one effect, which might otherwise cause confusion and trouble. At first, the wire of the long helix (2190.) was wound directly upon the thin glass tube which served to contain the fluid. When the electric current passed through the helix it raised the temperature of the metal, and that gradually raised the temperature of the glass and the film of water in contact with it, and so the cylinder of water, warmer at its surface than its axis, acted as a lens, gathering and sending rays of light to the eye, and continuing to act for a time after the current was stopped. By separating the tube of water from the helix, and by other precautions, this source of confusion is easily avoided.

2214. Another point of which the experimenter should be aware, is the difficulty, and almost impossibility, of obtaining a piece of glass which, especially after it is cut, does not depolarize light. When it does depolarize, difference of position makes an immense difference in the appearance. By always referring to the parts that do not depolarize, as the black cross, for instance, and by bringing the eye as near as may be to the glass, this difficulty is more or less overcome.

2215. For the sake of supplying a general indication of the amount of this induced rotating force in two or three bodies, and without any pretence of offering correct numbers, I will give, generally, the result of a few attempts to measure the force, and compare it with the natural power of a specimen of oil of turpentine. A very powerful electro-magnet was employed, with a *constant* distance between its poles of 2½ inches. In this space was placed different substances; the amount of rotation of the eye-piece observed several times and the average taken, as expressing the rotation for the ray length of substance used. But as the substances were of different dimensions, the ray lengths were, by calculation, corrected to one standard length, upon the assumption that the power was proportionate to this length (2163.). The oil of turpentine was of course observed in its natural state, i. e. without magnetic action. Making water 1, the numbers were as follows:—

Oil of turpentine	11·8
Heavy glass (2151.) . . .	6·0
Flint-glass	2·8
Rock salt	2·2

Water	1·0
Alcohol	less than water.
Ether	less than alcohol.

2216. In relation to the action of magnetic and electric forces on light, I consider that to know the conditions under which there is no apparent action, is to add to our knowledge of their mutual relations; and will, therefore, very briefly state how I have lately combined these forces, obtaining no apparent result (955.).

2217. Heavy glass, flint-glass, rock crystal, Iceland spar, oil of turpentine, and air had a polarized ray passed through them; and, at the same time, lines of electrostatic tension (2149.) were, by means of coatings, the Leyden jar, and the electric machine, directed across the bodies, parallel to the polarized ray, and perpendicular to it, both in and across the plane of polarization; but without any visible effect The tension of a rapidly recurring, induced secondary current, was also directed upon the same bodies and upon water (as an electrolyte), but with the same negative result.

2218. A polarized ray, powerful magnetic lines of force, and the electric lines of force (2149.) just described, were combined in various directions in their action on heavy glass (2151. 2176.), but with no other result than that due to the mutual action of the magnetic lines of light, already described in this paper.

2219. A polarized ray and electric currents were combined in every possible way in electrolytes (951–954). The substances used were distilled water, solution of sugar, dilute sulphuric acid, solution of sulphate of soda, using platinum electrodes and solution of sulphate of copper, using copper electrodes: the current was sent along the ray, and perpendicular to it in two directions at right angles with each other; the ray was made to rotate, by altering the position of the polarizing mirror that the plane of polarization might be varied; the current was used as a continuous current, as a rapidly intermitting current, and as a rapidly alternating double current of induction; but in no case was any trace of action perceived.

2220. Lastly, a ray of polarized light, electric currents, and magnetic lines of force were directed in every possible way through dilute sulphuric acid and solution of sulphate of soda, but still with negative results, except in those positions where the phenomena already described were produced. In one arrangement, the current passed in the direction of radii from a central to a circumferential electrode, the contrary magnetic poles being placed above and below; and the arrangements were so good, that when the electric current was passing, the fluid rapidly rotated; but a polarized ray sent horizontally across this arrangement was not at all affected. Also when the ray was sent vertically through it, and the eye-piece moved to correspond to the rotation impressed upon the ray in this position by the magnetic curves alone the superinduction of the passage of the electric current made not the least difference in the effect upon the ray.

¶ iii. *General considerations.*

2221. Thus is established, I think for the first time[*], a true, direct relation and dependence between light and the magnetic and electric forces; and thus a great addition made to the facts and considerations which tend to prove that all natural forces are tied together, and have one common origin (2146.). It is, no doubt, difficult in the present state of our knowledge to express our expectation in exact terms; and, though I have said that another of the powers of nature is, in these experiments, directly related to the rest, I ought, perhaps, rather to say that another form of the great power is distinctly and directly related to the other forms; or, that the great power manifested by particular phenomena in particular forms, is here further identified and recognised, by the direct relation of its form of light to its forms of electricity and magnetism.

2222. The relation existing between *polarized* light and magnetism and electricity, is even more interesting than if it had been shown to exist with common light only. It cannot but extend to common light; and, as it belongs to light made, in a certain respect, more precise in its character and properties by polarization, it collates and connects it with these powers, in that duality of character which they possess, and yields an opening, which before was wanting to us, for the appliance of these powers to the investigation of the nature of this and other radiant agencies.

2223. Referring to the conventional distinction before made (2149.), it may be again stated, that it is the magnetic lines of force *only* which are effectual on the rays of light, and they *only* (in appearance) when parallel to the ray of light, or as they tend to parallelism with it. As, in reference to matter not magnetic after the manner of iron, the phenomena of electric induction and electrolyzation show a vast superiority in the energy with which electric forces can act as compared to magnetic forces, so here, in another direction and in the peculiar and correspondent effects which belong to magnetic forces, they are shown, in turn, to possess great superiority, and to have their full equivalent of action on the same kind of matter.

2224. The magnetic forces do not act on the ray of light directly and without the intervention of matter, but through the mediation of the substance in which they and the ray have a simultaneous existence; the substances and the forces giving to and receiving from each other the power of acting on the light. This is shown by the ion-action of a vacuum, of air or gases; and it is also further shown by the special legree in which different matters possess the property. That magnetic force acts ipon the ray of light always with the same character of manner and in the same direction, independent of the different varieties of substance, or their states of solid or iquid, or their specific rotative force (2232.), shows that the magnetic force and the light have a direct relation: but that substances are necessary, and that these act in different degrees, shows that the magnetism and the light act on each other through the intervention of the matter.

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[*] I say, for the first time, because I do not think that the experiments of Morrichini on the production of magnetism by the rays at the violet end of the spectrum prove any such relation. When in Rome with Sir H. Davy in the month of May 1814, I spent several hours at the house of Morrichini, working with his apparatus and under his directions, but could not succeed in magnetising a needle. I have no confidence in the effect as a *direct* result of the action of the sun's rays; but think, that when it has occurred it has been secondary, incidental, and perhaps even accidental; a result that might well happen with a needle that was preserved during the whole experiment in a north and south position.

January 2, 1846.—I should not have written "for the first time," as above, if I had remembered Mr. Christie's experiments and papers on the Influence of the Solar Rays on Magnets, communicated in the Philosophical Transactions for 1826, p. 219, and 1828, p. 379.—M. F.

2225. Recognizing or perceiving *matter* only by its powers, and knowing nothing of any imaginary nucleus, abstract from the idea of these powers, the phenomena described in this paper much strengthen my inclination to trust in the views I have on a former occasion advanced in reference to its nature *.

2226. It cannot be doubted that the magnetic forces act upon and affect the internal constitution of the diamagnetic, just as freely in the dark as when a ray of light is passing through it; though the phenomena produced by light seem, as yet, to present the only means of observing this constitution and the change. Further, any such change as this must belong to opake bodies, such as wood, stone, and metal; for as diamagnetics, there is no distinction between them and those which are transparent. The degree of transparency can at the utmost, in this respect, only make a distinction between the individuals of a class.

2227. If the magnetic forces had made these bodies magnets, we could, by light, have examined a transparent magnet; and that would have been a great help to our investigation of the forces of matter. But it does not make them magnets (2171.), and therefore the molecular condition of these bodies, when in the state described, must be specifically distinct from that of magnetized iron, or other such matter, and must be *a new magnetic condition*; and as the condition is a state of tension (manifested by its instantaneous return to the normal state when the magnetic induction is removed), so the *force* which the matter in this state possesses and its mode of action, must be to us a *new magnetic force* or *mode of action* of matter.

2228. For it is impossible, I think, to observe and see the action of magnetic forces, rising in intensity, upon a piece of heavy glass or a tube of water, without also perceiving that the latter acquire properties which are not only *new* to the substance, but are also in subjection to very definite and precise laws (2160. 2199.), and are equivalent in proportion to the magnetic forces producing them.

2229. Perhaps this state is a state of *electric tension tending to a current*; as in magnets, according to AMPÈRE's theory, the state is a state of *current*. When a core of iron is put into a helix, every thing leads us to believe that currents of electricity are produced within it, which rotate or move in a plane perpendicular to the axis of the helix. If a diamagnetic be placed in the same position, it acquires power to make light rotate in the same plane. The state it has received is a state of tension, but i has not passed on into currents, though the acting force and every other circumstance and condition are the same as those which do produce currents in iron, nickel, cobalt, and such other matters as are fitted to receive them. Hence the idea that there exists in diamagnetics, under such circumstances, a tendency to currents, is consistent with all the phenomena as yet described, and is further strengthened by the fact, that, leaving the loadstone or the electric current, which by inductive action is rendering a piece of iron, nickel, or cobalt magnetic, perfectly unchanged, a mere change of temperature will take from these bodies their extra power, and make them pass into the common class of diamagnetics.

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* [illegible] Philosophical Magazine, 1844, vol. xxiv. p. 136.

2230. The present is, I believe, the first time that the molecular condition of a body, required to produce the circular polarization of light, has been artificially given; and it is therefore very interesting to consider this known state and condition of the body, comparing it with the relatively unknown state of those which possess the power naturally: especially as some of the latter rotate to the right-hand and others to the left; and, as in the cases of quartz and oil of turpentine, the same body chemically speaking, being in the latter instance a liquid with particles free to move, presents different specimens, some rotating one way and some the other.

2231. At first one would be inclined to conclude that the natural state and the state conferred by magnetic and electric forces must be the same, since the effect is the same; but on further consideration it seems very difficult to come to such a conclusion. Oil of turpentine will rotate a ray of light, the power depending upon its particles and not upon the arrangement of the mass. Whichever way a ray of polarized light passes through this fluid, it is rotated in the same manner; and rays passing in every possible direction through it *simultaneously* are all rotated with equal force and according to one common law of direction; *i. e.* either all right-handed or else all to the left. Not so with the rotation superinduced on the *same* oil of turpentine by the magnetic or electric forces: it exists only in one direction, *i. e.* in a plane perpendicular to the magnetic line; and being limited to this plane, it can be changed in direction by a reversal of the direction of the inducing force. The direction of the rotation produced by the natural state is connected invariably with the direction of the ray of light; but the power to produce it appears to be possessed in every direction and at all times by the particles of the fluid: the direction of the rotation produced by the induced condition is connected invariably with the direction of the magnetic line or the electric current, and the condition is possessed by the particles of matter, but strictly limited by the line or the current, changing and disappearing with it.

2232. Let *m*, in fig. 3, represent a glass cell filled with oil of turpentine, possessing naturally the power of producing right-hand rotation, and *a b* a polarized ray of light. If the ray proceed from *a* to *b*, and the eye be placed at *b*, the rotation will

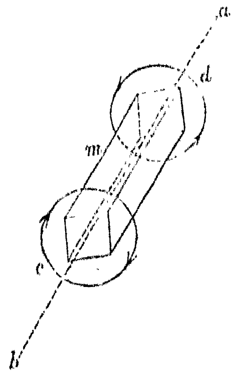
Fig. 3.

be right-handed, or according to the direction expressed by the arrow heads on the circle *c*; if the ray proceed from *b* to *a*, and the eye be placed at *a*, the rotation will still be right-handed *to the observer, i. e.* according to the direction indicated on the circle *d*. Let now an electric current pass round the oil of turpentine in the direction indicated on the circle *c*, or magnetic poles be placed so as to produce the same effect (2155.); the particles will acquire a further rotative force (which no motion amongst themselves will disturb), and a ray coming from *a* to *b* will be seen by an eye placed at *b* to rotate to the right-hand more than before, or in the direction on the circle *c*; but pass a ray from *b* to *a*, and observe with the eye at *a*, and the phenomenon is no longer the same as before; for instead of the new rotation being according to the direction indicated on the circle *d*, it will be in the contrary direction, or to the observer's left-hand (2199.). In fact the induced rotation will be added to the natural rotation as respects a ray passing from *a* to *b*, but it will be subtracted from the natural rotation as regards the ray passing from *b* to *a*. Hence the particles of this fluid which rotate by virtue of their natural force, and those which rotate by virtue of the induced force, cannot be in the same condition.

2233. As respects the power of the oil of turpentine to rotate a ray in whatever direction it is passing through the liquid, it may well be, that though all the particles possess the power of rotating the light, only those whose planes of rotation are more or less perpendicular to the ray affect it; and that it is the resultant or sum of forces in any one direction which is active in producing rotation. But even then a striking difference remains, because the resultant in the same plane is not absolute in direction, but relative to the course of the ray, being in the one case as the circle *c*, and in the other as the circle *d*, fig. 3; whereas the resultant of the magnetic or electric induction is absolute, and not changing with the course of the ray, being always either as expressed by *c* or else as indicated by *d*.

2234. All these differences, however, will doubtless disappear or come into harmony as these investigations are extended; and their very existence opens so many paths, by which we may pursue our inquiries, more and more deeply, into the powers and constitution of matter.

2235. Bodies having rotating power of themselves, do not seem by that to have a greater or a less tendency to assume a further degree of the same force under the influence of magnetic or electric power.

2236. Were it not for these and other differences, we might see an analogy between these bodies, which possess at all times the rotating power, as a specimen of quartz which rotates only in one plane, and those to which the power is given by the induction of other forces, as a prism of heavy glass in a helix, on the one hand; and, on the other, a natural magnet and a helix through which the current is passing.

The natural condition of the magnet and quartz, and the constrained condition of the helix and heavy glass, form the link of the analogy in one direction; whilst the supposition of currents existing in the magnet and helix, and only a tendency or tension to currents existing in the quartz and heavy glass, supplies the link in the transverse direction.

2237. As to those bodies which seem as yet to give no indication of the power over light, and therefore none of the assumption of the new magnetic conditions; these may be divided into two classes, the one including air, gases and vapours, and the other rock crystal, Iceland spar, and certain other crystalline bodies. As regards the latter class, I shall give, in the next series of these researches, proofs drawn from phenomena of an entirely different kind, that they do acquire the new magnetic condition; and these being so disposed of for the moment, I am inclined to believe that even air and gases have the power to assume the peculiar state, and even to affect light, but in a degree so small that as yet it has not been made sensible. Still the gaseous state is such a remarkable condition of matter, that we ought not too hastily to assume that the substances which, in the solid and liquid state, possess properties even general in character, always carry these into their gaseous condition.

2238. Rock-salt, fluor-spar, and, I think, alum, affect the ray of light; the other crystals experimented with did not; these are equiaxed and singly refracting, the others are unequiaxed and doubly refracting. Perhaps these instances, with that of the rotation of quartz, may even now indicate a relation between magnetism, electricity, and the crystallizing forces of matter.

2239. All bodies are affected by helices as by magnets, and according to laws which show that the causes of the action are identical as well as the effects. This result supplies another fine proof in favour of the identity of helices and magnets, according to the views of AMPÈRE.

2240. The theory of static induction which I formerly ventured to set forth (1161, &c.), and which depends upon the action of the contiguous particles of the dielectric intervening between the inductric and the inducteous bodies, led me to expect that the same kind of dependence upon the intervening particles would be found to exist in magnetic action; and I published certain experiments and considerations on this point seven years ago (1709—1736.). I could not then discover any peculiar condition of the intervening substance or diamagnetic; but now that I have been able to make out such a state, which is not only a state of tension (2227.), but dependent entirely upon the magnetic lines which pass through the substance, I am more than ever encouraged to believe that the view then advanced is correct.

2241. Although the magnetic and electric forces *appear* to exert no power on the ordinary or on the depolarized ray of light, we can hardly doubt but that they have some special influence, which probably will soon be made apparent by experiment. Neither can it be supposed otherwise than that the same kind of action should take place on the other forms of radiant agents as heat and chemical force.

2242. This mode of magnetic and electric action, and the phenomena presented by it, will, I hope, greatly assist hereafter in the investigation of the nature of transparent bodies, of light, of magnets, and their action one on another, or on magnetic substances. I am at this time engaged in investigating the new magnetic condition, and shall shortly send a further account of it to the Royal Society. What the possible effect of the force may be in the earth as a whole, or in magnets, or in relation to the sun, and what may be the best means of causing light to evolve electricity and magnetism, are thoughts continually pressing upon the mind; but it will be better to occupy both time and thought, aided by experiment, in the investigation and development of real truth, than to use them in the invention of suppositions which may or may not be founded on, or consistent with fact.

Royal Institution,
Oct. 29, 1845.

II. *Experimental Researches in Electricity.—Twentieth Series.*

By Michael Faraday, *Esq., D.C.L. F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Cor. Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, &c. &c.*

Received December 6,—Read December 18, 1845.

§ 27. *On new magnetic actions, and on the magnetic condition of all matter**.

¶ i. *Apparatus required.* ¶ ii. *Action of magnets on heavy glass.* ¶ iii. *Action of magnets on other substances acting magnetically on light.* ¶ iv. *Action of magnets on the metals generally.*

2243. THE contents of the last series of these researches were, I think, sufficient to justify the statement, that a new magnetic condition (*i. e.* one new to our knowledge) had been impressed on matter by subjecting it to the action of magnetic and electric forces (2227.); which new condition was made manifest by the powers of action which the matter had acquired over light. The phenomena now to be described are altogether different in their nature; and they prove, not only a magnetic condition of the substances referred to unknown to us before, but also of many others, including a vast number of opake and metallic bodies, and perhaps all except the magnetic metals and their compounds: and they also, through that condition, present us with the means of undertaking the correlation of magnetic phenomena, and perhaps the construction of a theory of general magnetic action founded on simple fundamental principles.

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* My friend Mr. Wheatstone has this day called my attention to a paper by M. Becquerel, "On the magnetic actions excited in all bodies by the influence of very energetic magnets," read to the Academy of Sciences on the 27th of September 1827, and published in the Annales de Chimie, xxxvi. p. 337. It relates to the action of the magnet on a magnetic needle, on soft iron, on the deutoxide and tritoxide of iron, on the tritoxide alone, and on a needle of wood. The author observed, and quotes Coulomb as having also observed, that a needle of wood, under certain conditions, pointed *across* the magnetic curves; and he also states the striking fact that he had found a needle of wood place itself parallel to the wires of a galvanometer. These effects, however, he refers to a degree of magnetism less than that of the tritoxide of iron, but the same in character, for the bodies take the same position. The polarity of steel and iron is stated to be in the direction of the length of the substance, but that of tritoxide of iron, wood and gum-lac, most frequently in the direction of the width, and always when one magnetic pole is employed. "This difference of effect, which establishes a line of demarcation between these two species of phenomena, is due to this, that the magnetism being very feeble in the tritoxide of iron, wood, &c., we may neglect the reaction of the body on itself, and therefore the direct action of the bar ought to overrule it."

As the paper does not refer the phenomena of wood and gum-lac to an elementary *repulsive* action, nor show that they are common to an immense class of bodies, nor distinguish this class, which I have called diamagnetic, from the magnetic class; and, as it makes all magnetic action of one kind, whereas I show that there are two kinds of such action, as distinct from each other as positive and negative electric action are in their way, so I do not think I need alter a word or the date of that which I have written; but am most glad here to acknowledge M. Becquerel's important facts and labours in reference to this subject.—M. F. Dec. 5, 1845.

2244. The whole matter is so new, and the phenomena so varied and general, that I must, with every desire to be brief, describe much which at last will be found to concentrate under simple principles of action. Still, in the present state of our knowledge, such is the only method by which I can make these principles and their results sufficiently manifest.

¶ i. *Apparatus required.*

2245. The effects to be described require magnetic apparatus of great power, and under perfect command. Both these points are obtained by the use of electro-magnets, which can be raised to a degree of force far beyond that of natural or steel magnets; and further, can be suddenly altogether deprived of power, or made energetic to the highest degree, without the slightest alteration of the arrangement, or of any other circumstance belonging to an experiment.

2246. One of the electro-magnets which I use is that already described under the term Woolwich helix (2192.). The soft iron core belonging to it is twenty-eight inches in length and 2·5 inches in diameter. When thrown into action by ten pair of GROVE'S plates, either end will sustain one or two half-hundred weights hanging to it. The magnet can be placed either in the vertical or the horizontal position. The iron core is a cylinder with flat ends, but I have had a cone of iron made, two inches in diameter at the base and one inch in height, and this placed at the end of the core, forms a conical termination to it, when required.

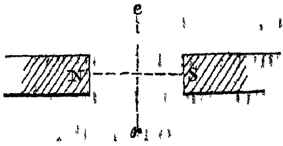
2247. Another magnet which I have had made has the horse-shoe form. The bar of iron is forty-six inches in length and 3·75 inches in diameter, and is so bent that the extremities forming the poles are six inches from each other; 522 feet of copper wire 0·17 of an inch in diameter and covered with tape, are wound round the two straight parts of the bar, forming two coils on these parts, each sixteen inches in length, and composed of three layers of wire: the poles are, of course, six inches apart, the ends are planed true, and against these move two short bars of soft iron, 7 inches long and 2½ by 1 inch thick, which can be adjusted by screws, and held at any distance less than six inches from each other. The ends of these bars form the opposite poles of contrary name; the magnetic field between them can be made of greater or smaller extent, and the intensity of the lines of magnetic force be proportionately varied.

2248. For the suspension of substances between and near the poles of these magnets, I occasionally used a glass jar, with a plate and sliding wire at the top. Six or eight lengths of cocoon silk being equally stretched, were made into one thread and attached, at the upper end, to the sliding rod, and at the lower end to a stirrup of paper, in which anything to be experimented on could be sustained.

2249. Another very useful mode of suspension was to attach one end of a fine thread, six feet long, to an adjustible arm near the ceiling of the room, and terminating at the lower end by a little ring of copper wire; any substance to be suspended could be held in a simple cradle of fine copper wire having eight or ten inches of the wire prolonged upward; this, being bent into a hook at the superior extremity, gave the means of attachment to the ring. The height of the suspended substance could be varied at pleasure, by bending any part of the wire at the instant into the hook form. A glass cylinder placed between the magnetic poles was quite sufficient to keep the suspended substance free from any motion, due to the agitation of the air.

2250. It is necessary, before entering upon an experimental investigation with such an apparatus, to be aware of the effect of any magnetism which the bodies used may possess; the power of the apparatus to make manifest such magnetism is so great, that it is difficult on that account to find writing-paper fit for the stirrup above mentioned. Before therefore any experiments are instituted, it must be ascertained that the suspending apparatus employed does not point, *i. e.* does not take up a position parallel to the line joining the magnetic poles, by virtue of the magnetic force. When copper suspensions are employed, a peculiar effect is produced (2309.), but when understood, as it will be hereafter, it does not interfere with the results of experiment. The wire should be fine, not magnetic as iron, and the form of the suspending cradle should not be elongated horizontally, but be round or square as to its general dimensions, in that direction.

2251. The substances to be experimented with should be carefully examined, and rejected if not found free from magnetism. Their state is easily ascertained; for, if magnetic, they will either be attracted to the one or the other pole of the great magnet, or else point between them. No examination by smaller magnets, or by a magnetic needle, is sufficient for this purpose.



2252. I shall have such frequent occasion to refer to two chief directions of position across the magnetic field, that to avoid periphrasis, I will here ask leave to use a term or two, conditionally. One of these directions is that from pole to pole, or along the line of magnetic force; I will call it the axial direction: the other is the direction perpendicular to this, and across the line of magnetic force; and for the time, and as respects the space between the poles, I will call it the equatorial direction. Other terms that I may use, I hope will explain themselves.

¶ ii. *Action of magnets on heavy glass.*

2253. The bar of silicated borate of lead, or heavy glass already described as the substance in which magnetic forces were first made effectually to bear on a ray of light (2152.), and which is two inches long, and about 0·5 of an inch wide and thick, was suspended centrally between the magnetic poles (2247.), and left until the effect of torsion was over. The magnet was then thrown into action by making contact at the voltaic battery: immediately the bar moved, turning round its point of suspension, into a position across the magnetic curve or line of force, and after a few vibrations took up its place of rest there. On being displaced by hand from this position, it returned to it, and this occurred many times in succession.

2254. Either end of the bar indifferently went to either side of the axial line. The determining circumstance was simply inclination of the bar one way or the other to the axial line, at the beginning of the experiment. If a particular or marked end of the bar were on one side of the magnetic, or axial line, when the magnet was rendered active that end went further outwards, until the bar had taken up the equatorial position.

2255. Neither did any change in the magnetism of the poles, by change in the direction of the electric current, cause any difference in this respect. The bar went by the shortest course to the equatorial position.

2256. The power which urged the bar into this position was so thoroughly under command, that if the bar were swinging it could easily be hastened in its course into this position, or arrested as it was passing from it, by seasonable contacts at the voltaic battery.

2257. There are two positions of equilibrium for the bar; one stable, the other unstable. When in the direction of the axis or magnetic line of force, the completion of the electric communication causes no change of place; but if it be the least oblique to this position, then the obliquity increases until the bar arrives at the equatorial position; or if the bar be originally in the equatorial position, then the magnetism causes no further changes, but retains it there (2298. 2299. 2384.).

2258. Here then we have a magnetic bar which points east and west, in relation to north and south poles, *i. e.* points perpendicularly to the lines of magnetic force.

2259. If the bar be adjusted so that its point of suspension, being in the axial line, is not equidistant from the poles, but near to one of them, then the magnetism again makes the bar take up a position perpendicular to the magnetic lines of force; either end of the bar being on the one side of the axial line, or the other, at pleasure. But at the same time there is another effect, for at the moment of completing the electric contact, the centre of gravity of the bar recedes from the pole and remains repelled from it as long as the magnet is retained excited. On allowing the magnetism to pass away, the bar returns to the place due to it by its gravity.

2260. Precisely the same effect takes place at the other pole of the magnet. Either of them is able to repel the bar, whatever its position may be, and at the same time the bar is made to assume a position, at right angles, to the line of magnetic force

2261. If the bar be equidistant from the two poles, and in the axial line, then no repulsive effect is or can be observed.

2262. But preserving the point of suspension in the equatorial line, i. e. equidistant from the two poles, and removing it a little on one side or the other of the axial line (2252.), then another effect is brought forth. The bar points as before across the magnetic line of force, but at the same time it recedes from the axial line, increasing its distance from it, and this new position is retained as long as the magnetism continues, and is quitted with its cessation.

2263. Instead of two magnetic poles, a single pole may be used, and that either in a vertical or a horizontal position. The effects are in perfect accordance with those described above; for the bar, when near the pole, is repelled from it in the direction of the line of magnetic force, and at the same time it moves into a position perpendicular to the direction of the magnetic lines passing through it. When the magnet is vertical (2246.) and the bar by its side, this action makes the bar a tangent to the curve of its surface.

2264. To produce these effects, of pointing across the magnetic curves, the form of the heavy glass must be long; a cube, or a fragment approaching roundness in form, will not point, but a long piece will. Two or three rounded pieces or cubes, placed side by side in a paper tray, so as to form an oblong accumulation, will also point.

2265. Portions, however, of any form, are *repelled*: so if two pieces be hung up at once in the axial line, one near each pole, they are repelled by their respective poles, and approach, seeming to attract each other. Or if two pieces be hung up in the equatorial line, one on each side of the axis, then they both recede from the axis, seeming to repel each other.

2266. From the little that has been said, it is evident that the bar presents in its motion a complicated result of the force exerted by the magnetic power over the heavy glass, and that, when cubes or spheres are employed, a much simpler indication of the effect may be obtained. Accordingly, when a cube was thus used with the two poles, the effect was repulsion or recession from either pole, and also recession from the magnetic axis on either side.

2267. So, the indicating particle would move, either along the magnetic curves, or across them; and it would do this either in one direction or the other; the only constant point being, that its tendency was to move from stronger to weaker places of magnetic force.

2268. This appeared much more simply in the case of a single magnetic pole, for then the tendency of the indicating cube or sphere was to move outwards, in the direction of the magnetic lines of force. The appearance was remarkably like a case of weak electric repulsion.

2269. The cause of the pointing of the bar, or any oblong arrangement of the heavy glass, is now evident. It is merely a result of the tendency of the particles to move outwards, or into the positions of weakest magnetic action. The joint exertion of the action of all the particles brings the mass into the position, which, by experiment, is found to belong to it.

2270. When one or two magnetic poles are active at once, the courses described by particles of heavy glass free to move, form a set of lines or curves, which I may have occasion hereafter to refer to; and as I have called air, glass, water, &c. diamagnetics (2149.), so I will distinguish these lines by the term *diamagnetic curves*, both in relation to, and contradistinction from, the lines called magnetic curves.

2271. When the bar of heavy glass is immersed in water, alcohol, or ether, contained in a vessel between the poles, all the preceding effects occur; the bar points and the cube recedes exactly in the same manner as in air.

2272. The effects equally occur in vessels of wood, stone, earth, copper, lead, silver, or any of those substances which belong to the diamagnetic class (2149.).

2273. I have obtained the same equatorial direction and motions of the heavy glass bar as those just described, but in a very feeble degree, by the use of a good common steel horse-shoe magnet (2157.). I have not obtained them by the use of the helices (2191. 2192.) without the iron cores.

2274. Here therefore we have magnetic repulsion without polarity, i. e. without reference to a particular pole of the magnet, for either pole will repel the substance, and both poles will repel it at once (2262.). The heavy glass, though subject to magnetic action, cannot be considered as magnetic, in the usual acceptation of that term, or as iron, nickel, cobalt, and their compounds. It presents to us, under these circumstances, a magnetic property new to our knowledge; and though the phenomena are very different in their nature and character to those presented by the action of the heavy glass on light (2152.), still they appear to be dependent on, or connected with, the same condition of the glass as made it then effective, and therefore, with those phenomena, prove the reality of this new condition.

¶ iii. *Action of magnets on other substances acting magnetically on light.*

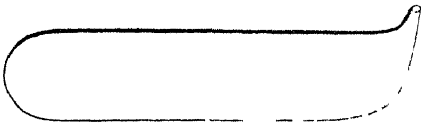
2275. We may now pass from heavy glass to the examination of the other substances, which, when under the power of magnetic or electric forces, are able to affect and rotate a polarized ray (2173.), and may also easily extend the investigation to bodies which, from their irregularity of form, imperfect transparency, or actual opacity, could not be examined by a polarized ray, for here we have no difficulty in the application of the test to all such substances.

2276. The property of being thus repelled and affected by magnetic poles, was soon found not to be peculiar to heavy glass. Borate of lead, flint-glass, and crown-glass set in the same manner equatorially, and were repelled when near to the poles, though not to the same degree as the heavy glass.

2277. Amongst substances which could not be subjected to the examination by light, phosphorus in the form of a cylinder presented the phenomena very well; I think as powerfully as heavy glass, if not more so. A cylinder of sulphur, and a long piece of thick India rubber, neither being magnetic after the ordinary fashion, were well directed and repelled.

2278. Crystalline bodies were equally obedient, whether taken from the single or double refracting class (2237.). Prisms of quartz, calcareous spar, nitre and sulphate of soda, all pointed well, and were repelled.

2279. I then proceeded to subject a great number of bodies, taken from every class, to the magnetic forces, and will, to illustrate the variety in the nature of the substances, give a comparatively short list of crystalline, amorphous, liquid and organic bodies below. When the bodies were fluids, I inclosed them in thin glass tubes. Flint-glass points equatorially, but if the tube be of very thin glass, this effect is found to be small when the tube is experimented with alone; afterwards, when it is filled with liquid and examined, the effect is such that there is no fear of mistaking that due to the glass for that of the fluid. The tubes must not be closed with cork, sealing-wax, or any ordinary substance taken at random, for these are generally magnetic (2285.). I have usually so shaped them in the making, and drawn them off at the neck, as to leave the aperture on one side, so that when filled with liquid they required no closing.



2280. Rock crystal.
Sulphate of lime.
Sulphate of baryta.
Sulphate of soda.
Sulphate of potassa.
Sulphate of magnesia.
Alum.
Muriate of ammonia.
Chloride of lead.
Chloride of sodium.
Nitrate of potassa.
Nitrate of lead.
Carbonate of soda.
Iceland spar.
Acetate of lead.
Tartrate of potash and antimony.
Tartrate of potash and soda.
Tartaric acid.
Citric acid.
Water.
Alcohol.
Ether.
Nitric acid.
Sulphuric acid.
Muriatic acid.
Solutions of various alkaline and earthy salts.
Glass.
Litharge.
White arsenic.
Iodine.
Phosphorus.
Sulphur.
Resin.
Spermaceti.
Caffeine.
Cinchonia.
Margaric acid.
Wax from shell-lac.
Sealing-wax.
Olive-oil.
Oil of turpentine.
Jet.
Caoutchouc.

Sugar.
Starch.
Gum-arabic.
Wood.
Ivory.
Mutton, dried.
Beef, fresh.
Beef, dried.
Blood, fresh.
Blood, dried.
Leather.
Apple.
Bread.

2281. It is curious to see such a list as this of bodies presenting on a sudden this remarkable property, and it is strange to find a piece of wood, or beef, or apple, obedient to or repelled by a magnet. If a man could be suspended, with sufficient delicacy, after the manner of DUFAY, and placed in the magnetic field, he would point equatorially; for all the substances of which he is formed, including the blood, possess this property.

2282. The setting equatorially depends upon the form of the body, and the diversity of form presented by the different substances in the list was very great; still the general result, that elongation in one direction was sufficient to make them take up an equatorial position, was established. It was not difficult to perceive that comparatively large masses would point as readily as small ones, because in larger masses more lines of magnetic force would bear in their action on the body, and this was proved to be the case. Neither was it long before it evidently appeared that the form of a plate or a ring was quite as good as that of a cylinder or a prism; and in practice it was found that plates and flat rings of wood, spermaceti, sulphur, &c., if suspended in the right direction, took up the equatorial position very well. If a plate or ring of heavy glass could be floated in water, so as to be free to move in every direction, and were in that condition subject to magnetic forces diminishing in intensity, it would immediately set itself equatorially, and if its centre coincided with the axis of magnetic power, would remain there; but if its centre were out of this line, it would then, perhaps, gradually pass off from this axis in the plane of the equator, and go out from between the poles.

2283. I do not find that division of the substance has any distinct influence on the effects. A piece of Iceland spar was observed, as to the degree of force with which it set equatorially; it was then broken into six or eight fragments, put into a glass tube and tried again; as well as I could ascertain, the effect was the same. By a second operation, the calcareous spar was reduced into coarse particles; afterwards to a coarse powder, and ultimately to a fine powder: being examined as to the equatorial set each time, I could perceive no difference in the effect, until the very last, when I thought there might be a slight diminution of the tendency, but if so, it was almost insensible. I made the same experiment on silica with the same result, of no diminution of power. In reference to this point I may observe, that starch and other bodies in fine powder exhibited the effect very well.

2284. It would require very nice experiments and great care to ascertain the specific degree of this power of magnetic action possessed by different bodies, and I have made very little progress in that part of the subject. Heavy glass stands above flint-glass, and the latter above plate-glass. Water is beneath all these, and I think alcohol is below water, and ether below alcohol. The borate of lead is I think as high as heavy glass, if not above it, and phosphorus is probably at the head of all the substances just named. I verified the equatorial set of phosphorus between the poles of a common magnet (2273.).

2285. I was much impressed by the fact that blood was not magnetic (2280.), nor any of the specimens tried of red muscular fibre of beef or mutton. This was the more striking, because, as will be seen hereafter, iron is *always* and in almost *all states* magnetic. But in respect to this point it may be observed, that the ordinary magnetic property of matter and this *new property* are in their effects opposed to each other; and that when this property is strong it may overcome a very slight degree of ordinary magnetic force, just as also a certain amount of the magnetic property may oppose and effectually hide the presence of this force (2422.). It is this circumstance which makes it so necessary to be careful in examining the magnetic condition of the bodies in the first instance (2250.). The following list of a few substances, which were found slightly magnetic, will illustrate this point:—Paper, sealing-wax, china ink, Berlin porcelain, silkworm-gut, asbestos, fluor-spar, red lead, vermilion, peroxide of lead, sulphate of zinc, tourmaline, plumbago, shell-lac, charcoal. In some of these cases the magnetism was generally diffused through the body, in other cases it was limited to a particular part.

2286. Having arrived at this point, I may observe, that we can now have no difficulty in admitting that the phenomena abundantly establish the existence of a magnetic property in matter, new to our knowledge. Not the least interesting of the consequences that flow from it, is the manner in which it disposes of the assertion which has sometimes been made, that all bodies are magnetic. Those who hold this view, mean that all bodies are magnetic as iron is, and say that they point between the poles. The new facts give not a mere negative to this statement, but something beyond, namely, an affirmative as to the existence of forces in all ordinary bodies, directly the opposite of those existing in magnetic bodies, for whereas those practically produce attraction, these produce repulsion; those set a body in the axial direction, but these make it take up an equatorial position: and the facts with regard to bodies generally, are exactly the reverse of those which the view quoted indicates.

¶ iv. *Action of magnets on metals generally.*

2287. The metals, as a class, stand amongst bodies having a high and distinct interest in relation both to magnetic and electric forces, and might at first well be expected to present some peculiar phenomena, in relation to the striking property found to be possessed in common by so large a number of substances, so varied in their general characters. As yet no distinction associated with conduction or non-conduction, transparent or opake, solid or liquid, crystalline or amorphous, whole or broken, has presented itself; whether the metals, distinct as they are as a class, would fall into the great generalization, or whether at last a separation would occur, was to me a point of the highest interest.

2288. That the metals, iron, nickel and cobalt, would stand in a distinct class, appeared almost undoubted; and it will be, I think, for the advantage of the inquiry, that I should consider them in a section apart by themselves. Further, if any other metals appeared to be magnetic, as these are, it would be right and expedient to include them in the same class.

2289. My first point, therefore, was to examine the metals for any indication of ordinary magnetism. Such an examination cannot be carried on by magnets anything short in power of those to be used in the further investigation; and in proof of this point I found many specimens of the metals, which appeared to be perfectly free from magnetism when in the presence of a magnetic needle, or a strong horseshoe magnet (2157.), that yet gave abundant indications when suspended near to one or both poles of the magnets described (2216.).

2290. My test of magnetism was this. If a bar of the metal to be examined, about two inches long, was suspended (2249.) in the magnetic field, and being at first oblique to the axial line, was upon the supervention of the magnetic forces drawn into the axial position instead of being driven into the equatorial line, or remaining in some oblique direction, then I considered it magnetic. Or, if being near one magnetic pole, it was attracted by the pole, instead of being repelled, then I concluded it was magnetic. It is evident that the test is not strict, because, as before pointed out (2285.), a body may have a slight degree of magnetic force, and yet the power of the new property be so great as to neutralize or surpass it. In the first case, it might seem neither to have the one property nor the other; in the second case, it might appear free from magnetism, and possessing the special property in a *small* degree.

2291. I obtained the following metals, so that when examined as above, they did not appear to be magnetic; and in fact if magnetic, were so to an amount so small as not to destroy the results of the other force, or to stop the progress of the inquiry.

Antimony.
Bismuth.
Cadmium.
Copper.
Gold.
Lead.
Mercury.
Silver.
Tin.
Zinc.

2292. The following metals were, and are as yet to me, magnetic, and therefore companions of iron, nickel and cobalt:—

Platinum.
Palladium.
Titanium.

2293. Whether all these metals are magnetic, in consequence of the presence of a little iron, nickel, or cobalt in them, or whether any of them are really so of themselves, I do not undertake to decide at present; nor do I mean to say that the metals of the former list are free. I have been much struck by the apparent freedom from iron of almost all the specimens of zinc, copper, antimony and bismuth, which I have examined; and it appears to me very likely that some metals, as arsenic, &c., may have much power in quelling and suppressing the magnetic properties of any portion of iron in them, whilst other metals, as silver or platinum, may have little or no power in this respect.

2294. Resuming the consideration of the influence excited by the magnetic force over those metals which are not magnetic after the manner of iron (2291.), I may state that there are two sets of effects produced which require to be carefully distinguished. One of these depends upon induced magneto-electric currents, and shall be resumed hereafter (2309.). The other includes effects of the same nature as those produced with heavy glass and many other bodies (2276.).

2295. All the non-magnetic metals are subject to the magnetic power, and produce the same general effects as the large class of bodies already described. The force which they then manifest, they possess in different degrees. Antimony and bismuth show it well, and bismuth appears to be especially fitted for the purpose. It excels heavy glass, or borate of lead, and perhaps phosphorus; and a small bar or cylinder of it about two inches long, and from 0·25 to 0·5 of an inch in width, is as well fitted to show the various peculiar phenomena as anything I have yet submitted to examination.

2296. To speak accurately, the bismuth bar which I employed was two inches long, 0·33 of an inch wide, and 0·2 of an inch thick. When this bar was suspended in the magnetic field, between the two poles, and subject to the magnetic force, it pointed freely in the equatorial direction, as the heavy glass did (2253.), and if disturbed from that position, returned *freely* to it. This latter point, though perfectly in accordance with the former phenomena, is in such striking contrast with the phenomena presented by copper and some other of the metals (2309.), as to require particular notice here.

2297. The comparative sensibility of bismuth causes several movements to take place under various circumstances, which being complicated in their nature, require careful analysis and explanation. The chief of these, with their causes, I will proceed to point out.

2298. If the cylinder electro-magnet (2246.) be placed vertically so as to present one pole upwards, that pole will exist in the upper end of an iron cylinder, having a flat horizontal face 2½ inches in diameter. A small indicating sphere (2266.) of bismuth hung over the centre of this face and close to it, does not move by the magnetism. If the ball be carried outwards, half way, for instance, between the centre and the edge, the magnetism makes it move inwards, or towards the axis (prolonged) of the iron cylinder. If carried still further outwards, it still moves inwards under the influence of the magnetism, and such continues to be the case until it is placed just over the edge of the terminal face of the core, where it has no motion at all (here, by another arrangement of the experiment, it is known to tend in what is at present an upward direction from the core). If carried a little further outwards, the magnetism then makes the bismuth ball tend to go outwards or be repelled, and such continues to be the direction of the force in any further position, or down the side of the end of the core.

2299. In fact, the circular edge formed by the intersection of the end of the core with its sides, is virtually the apex of the magnetic pole, to a body placed like the bismuth ball close to it, and it is because the lines of magnetic force issuing from it diverge as it were, and weaken rapidly in all directions from it, that the ball also tends to pass in all directions either inwards or upwards, or outwards from it, and thus produces the motions described. These same effects do not in fact all occur when the ball, being taken to a greater distance from the iron, is placed in magnetic curves, having generally a simpler direction. In order to remove the effect of the edge, an iron cone was placed on the top of the core, converting the flat end into a cone, and then the indicating ball was urged to move upwards, only when over the apex of the cone, and upward and outwards, as it was more or less on one side of it, being always repelled from the pole in that direction, which transferred it most rapidly from strong to weaker points of magnetic force.

2300. To return to the vertical flat pole: when a horizontal bar of bismuth was suspended concentrically and close to the pole, it could take up a position in any direction relative to the axis of the pole, having at the same time a tendency to move upwards or be repelled from it. If its point of suspension was a little excentric, the bar gradually turned, until it was parallel to a line joining its point of suspension with the prolonged axis of the pole, and the centre of gravity moved inwards. When its point of suspension was just outside the edge of the flat circular terminating face, and the bar formed a certain angle with a radial line joining the axis of the core and the point of suspension, then the movements of the bar were uncertain and wavering. If the angle with the radial line were less than that above, the bar would move into parallelism with the radius and go inwards: if the angle were greater, the bar would move until perpendicular to the radial line and go outwards. If the centre of the bar were still further out than in the last case, or down by the side of the core, the bar would always place itself perpendicular to the radius and go outwards. All these complications of motion are easily resolved into their simple elementary origin, if reference be had to the character of the circular angle bounding the end of the core; to the direction of the magnetic lines of force issuing from it and the other parts of the pole; to the position of the different parts of the bar in these lines; and the ruling principle that each particle tends to go by the nearest course from *strong* to *weaker* points of magnetic force.

2301. The bismuth points well, and is well repelled (2296.) when immersed in water, alcohol, ether, oil, mercury, &c., and also when inclosed within vessels of earth, glass, copper, lead, &c. (2272.), or when screens of 0·75 or 1 inch in thickness of bismuth, copper, or lead intervene. Even when a bismuth cube (2266.) was placed in an iron vessel 2½ inches in diameter and 0·17 of an inch in thickness, it was well and freely repelled by the magnetic pole.

2302. Whether the bismuth be in one piece or in very fine powder, appears to make no difference in the character or in the degree of its magnetic property (2283.).

2303. I made many experiments with masses and bars of bismuth suspended, or otherwise circumstanced, to ascertain whether two pieces had any mutual action on each other, either of attraction or repulsion, whilst jointly under the influence of the magnetic forces, but I could not find any indication of such mutual action: they appeared to be perfectly indifferent one to another, each tending only to go from stronger to weaker points of magnetic power.

2304. Bismuth, in very fine powder, was sprinkled upon paper, laid over the horizontal circular termination of the vertical pole (2246.). If the paper were tapped, the magnet not being excited, nothing particular occurred; but if the magnetic power were on, then the powder retreated in both directions, inwards and outwards, from a circular line just over the edge of the core, leaving the circle clear, and at the same time showing the tendency of the particles of bismuth in all directions from that line (2299.).

2305. When the pole was terminated by a cone (2246.) and the magnet not in action, paper with bismuth powder sprinkled over it being drawn over the point of the cone, gave no particular result; but when the magnetism was on, such an operation cleared the powder from every point which came over the cone, so that a mark was traced or written out in clear lines running through the powder, and showing every place where the pole had passed.

2306. The bar of bismuth and a bar of antimony was found to set equatorially between the poles of the ordinary horse-shoe magnet.

2307. The following list may serve to give an idea of the apparent order of some metals, as regards their power of producing these new effects, but I cannot be sure that they are perfectly free from the magnetic metals. In addition to that, there are certain other effects produced by the action of magnetism on metals (2309.) which greatly interfere with the results due to the present property.

Bismuth.
Antimony.
Zinc.
Tin.
Cadmium.
Mercury.
Silver.
Copper.

2308. I have a vague impression that the repulsion of bismuth by a magnet has been observed and published several years ago. If so, it will appear that what must then have been considered as a peculiar and isolated effect, was the consequence of a general property, which is now shown to belong to all matter*.

2309. I now turn to the consideration of some peculiar phenomena which are presented by copper and several of the metals when they are subjected to the action of magnetic forces, and which so tend to mask effects of the kind already described, that if not known to the inquirer they would lead to much confusion and doubt. These I will first describe as to their appearances, and then proceed to consider their origin.

2310. If instead of a bar of bismuth (2296.) a bar of copper of the same size be suspended between the poles (2247.), and magnetic power be developed whilst the bar is in a position oblique to the axial and equatorial lines, the experimenter will perceive the bar to be affected, but this will not be manifest by any tendency of the bar to go to the equatorial line; on the contrary, it will advance towards the axial position as if it were magnetic. It will not, however, continue its course until in that position, but, unlike any effect produced by magnetism, will stop short, and making no vibration beyond or about a given point, will remain there coming at once to a dead rest: and this it will do even though the bar by the effect of torsion or momentum was previously moving with a force that would have caused it to make several gyrations. This effect is in striking contrast with that which occurs when antimony, bismuth, heavy glass, or other such bodies are employed, and it is equally removed from an ordinary magnetic effect.

2311. The position which the bar has taken up it retains with a considerable degree of tenacity, provided the magnetic force be continued. If pushed out of it, it does not return into it, but takes up its new position in the same manner, and holds it with the same stiffness; a push however, which would make the bar spin round several times if no magnetism were present, will now not move it through more than 20° or 30°. This is not the case with bismuth or heavy glass; they vibrate freely in the magnetic field, and always return to the equatorial position.

2312. The position taken up by the bar may be any position. The bar is moved a little at the instant of superinducing the magnetism, but allowing and providing for that, it may be finally fixed in any position required. Even when swinging with considerable power by torsion or momentum, it may be caught and retained in any place the experimenter wishes.

2313. There are two positions in which the bar may be placed at the beginning of the experiment, from which the magnetism does not move it, the equatorial and the axial positions. When the bar is nearly midway between these, it is usually most strongly affected by the first action of the magnet, but the position of most effect varies with the form and dimensions of the magnetic poles and of the bar.

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* M. DE LA RIVE has this day referred me to the Bibliothèque Universelle for 1829, tome xl. p. 82, where it will be found that the experiment spoken of above is due to M. LA BAILLIF of Paris. M. LA BAILLIF showed sixteen years ago that both bismuth and antimony repelled the magnetic needle. It is astonishing that such an experiment has remained so long without further results. I rejoice that I am able to insert this reference before the present series of these researches goes to press. Those who read my papers will see here, as on many other occasions, the results of a memory which becomes continually weaker; I only hope that they will be excused, and that omissions and errors of that nature will be considered as involuntary.—M. F. December 30, 1845.

2314. If the centre of suspension of the bar be in the axial line, but near to one of the poles, these movements occur well, and are clear and distinct in their direction: if it be in the equatorial line, but on one side of the axial line, they are modified, but in a manner which will easily be understood hereafter.

2315. Having thus stated the effect of the supervention of the magnetic force, let us now remark what occurs at the moment of its cessation; for during its continuance there is no change. If, then, after the magnetism has been sustained for two or three seconds, the electric current be stopped, there is instantly a strong action on the bar, which has the appearance of a revulsion (for the bar returns upon the course which it took for a moment when the electric contact was made), but with such force, that whereas the advance might be perhaps 15° or 20°, the revulsion will cause the bar occasionally to move through two or three revolutions.

2316. Heavy glass or bismuth presents no such phenomena as this.

2317. If, whilst the bar is revolving from revulsion the electric current at the magnet be renewed, the bar instantly stops with the former appearances and results (2310.), and then upon removing the magnetic force is affected again, and, of course, now in a contrary direction to the former revulsion.

2318. When the bar is caught by the magnetic force in the axial or equatorial position, there is no revulsion. When inclined to these positions there is; and the places most powerful in this respect appear to be those most favourable to the first brief advance (2313.). If the bar be in a position at which strong revulsion would occur, and whilst the magnetism is continued be moved by hand into the equatorial or axial position, then on taking off the magnetic force there is no revulsion.

2319. If the continuance of the electric current and consequently of the magnetism be for a moment only, the revulsion is very little, and the shorter the continuance of the magnetic force the less is the revulsion. If the magnetic force be continued for two or three seconds and then interrupted and *instantly* renewed, the bar is loosened and caught again by the power before it sensibly changes its place; and now it may be observed that it does not advance on the *renewal* of the force as it would have done had it been acted on by a first contact in that place (2310.); *i. e.* if the bar be in a certain place inclined to the axial position, the first supervention of the magnetic power causes it to advance towards the axial position; but the bar being in the same place and the magnetic power suspended and *instantly* renewed, the second supervention of force does not move the bar as the first did.

2320. When the copper bar is immersed in water, alcohol, or even mercury, the same effects take place as in the air, but the movements are, of course, not to the same extent.

2321. When plates of copper or bismuth, an inch in thickness, intervene between the poles and the copper bar, the same results occur.

2322. If one magnetic pole only be employed the effects occur near it as well as before, provided that pole have a face large in proportion to the bar, as the end of the iron core (2246.): but if the pole be pointed by the use of the conical termination, or if the bar be opposite the edge of the end of the core, then they become greatly enfeebled or disappear altogether; and only the general fact of repulsion remains (2295.).

2323. The peculiar effects which have just been described are perhaps more strikingly shown if the bar of copper be suspended perpendicularly, and then hung opposite and near to the large face of a single magnetic pole, or the pole being placed vertically, as described (2246. 2263.), anywhere near to its side. The bar, it will be remembered, is two inches in length by 0·33 of an inch in width, and 0·2 of an inch in thickness, and as it now will revolve on an axis parallel to its length, the two smaller dimensions are those which are free to move into new positions. In this case the establishment of the magnetic force causes the bar to turn a little in accordance with the effects before described, and the removal of the magnetic force causes a revulsion, which sends the bar spinning round on its axis several times. But at any moment the bar can again be caught and held in a position as before. The tendency on making contact at the battery is to place the longest moving dimension, *i. e.* the width of the bar, parallel to the line joining the centre of action of the magnet and the bar.

2324. The bar, as before (2311.), is extremely sluggish and as if immersed in a dense fluid, as respects rotation on its own axis; but this sluggishness does not affect the bar as a whole, for any pendulum vibration it has continues unaffected. It is very curious to see the bar, jointly vibrating from its point of suspension (2249.) and rotating on its axis, when first affected by the magnetic force, for instantly the latter motion ceases, but the former goes on with undiminished power.

2325. The same effect of sluggishness occurs with a cube or a globe of copper as with the bar, but the phenomena of the first turn and the revulsion cease (2310. 2315.).

2326. The bars of bismuth and heavy glass present no appearance of this kind. The peculiar phenomena produced by copper are as distinct from the actions of these substances as they are from ordinary magnetic actions.

2327. Endeavouring to explain the cause of these effects, it appears to me that they depend upon the excellent conducting power of copper for electric currents, the gradual acquisition and loss of magnetic power by the iron core of the electro-magnet, and the production of those induced currents of magneto-electricity which I described in the First Series of these Experimental Researches (55. 109.).

2328. The obstruction to motion on its own axis, when the bar is subjected to the magnetic forces, belongs equally to the form of a sphere or a cube. It belongs to these bodies, however, only when their axes of rotation are perpendicular or oblique to the lines of magnetic force, and not when they are parallel to it; for the horizontal bar, or the vertical bar, or the cube or sphere, rotate with perfect facility when they are suspended *above* the vertical pole (2246.), the rotation and vibration being then equally free, and the same as the corresponding movements of bismuth or heavy glass. The obstruction is at a maximum when the axis of rotation is perpendicular to the lines of magnetic force, and when the bar or cube, &c. is near to the magnet.

2329. Without going much into the particular circumstances, I may say that the effect is fully explained by the electric currents induced in the copper mass. By reference to the Second Series of these Researches (160.)*, it will be seen that when a globe, subject to the action of lines of magnetic force, is revolving on an axis perpendicular to these lines, an electric current runs round it in a plane parallel to the axis of rotation and to the magnetic lines, producing consequently a magnetic axis in the globe, at right angles to the magnetic curves of the inducing magnet. The magnetic poles of this axis therefore are in that direction which, in conjunction with the chief magnetic pole, tends to draw the globe back against the direction in which it is revolving. Thus, if a piece of copper be revolving before a north magnetic pole, so that the parts nearest the pole move towards the right-hand, then the right-hand side of that copper will have a south magnetic state, and the left-hand side a north magnetic state; and these states will tend to counteract the motion of the copper towards the right hand: or if it revolve in the contrary direction, then the right-hand side will have a south magnetic state, and the left-hand side a north magnetic state. Whichever way, therefore, the copper tends to revolve on its own axis, the instant it moves, a power is evolved in such a direction as tends to stop its motion and bring it to rest. Being at rest in reference to this direction of motion, then there is no residual or other effect which tends to disturb it, and it remains still.

2330. If the whole mass be moving parallel to itself, and be small in comparison with the face of the magnetic pole opposite to which it is placed, then, though it pass through the magnetic lines of force, and consequently have a tendency to the formation of magneto-electric currents within it, yet as all parts move with equal velocity and in the same direction through similar magnetic lines of force, the tendency to the formation of a current is the same in every part, and there is no actual production of current, and consequently nothing occurs which can in any way interfere with its freedom of motion. Hence the reason that though the rotation of the bar or cube (2324. 2328.) upon its own axis is stopped, its vibration as a pendulum is not affected.

2331. That neither the one nor the other motion is affected when the bar or cube is over the vertical pole (2328.), is simply because in both cases (with the given dimensions of the pole and the moving metal) the lines of particles through which the induced currents tend to move are parallel throughout the whole mass; and therefore, as there is no part by which the return of the current can be carried on, no current can be formed.

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* Philosophical Transactions, 1832, p. 168.

2332. Before proceeding to the explanation of the other phenomena, it will be necessary to point out the fact generally understood and acknowledged, I believe, that time is required for the development of magnetism in an iron core by a current of electricity; and also for its fall back again when the current is stopped. One effect of the gradual rise in power was referred to in the last series of these Researches (2170.). This time is probably longer with iron not well annealed than with very good and perfectly annealed iron. The last portions of magnetism which a given current can develope in a certain core of iron, are also apparently acquired more slowly than the first portions; and these portions (or the condition of iron to which they are due) also appear to be lost more slowly than the other portions of the power. If electric contact be made for an instant only, the magnetism developed by the current disappears as instantly on the breaking of the current, as it appeared on its formation; but if contact be continued for three or four seconds, breaking the contact is by no means accompanied by a disappearance of the magnetism with equal rapidity.

2333. In order to trace the peculiar effect of the copper, and its cause, let us consider the condition of the horizontal bar (2310. 2313.) when in the equatorial position, between the two magnetic poles, or before a single pole; the point of suspension being in a line with the axis of the pole and its exciting wire helix. On sending an electric current through the helix, both it and the magnet it produces will conduce to the formation of currents in the copper bar in the contrary direction. This is shown from my former researches (26.), and may be proved, by placing a small or large wire helix-shaped (if it be desired) in the form of the bar, and carrying away the currents produced in it, by wires to a galvanometer at a distance. Such currents being produced in the copper, only continue whilst the magnetism of the core is rising and then cease (18. 39.), but *whilst* they continue, they give a virtual magnetic polarity to that face of the copper bar which is opposite to a certain pole, the polarity being the same in kind as the pole it faces. Thus on the side of the bar facing the north pole of the magnet, a north polarity will be developed; and on that side facing the south pole, a south polarity will be generated.

2334. It is easy to see that if the copper during this time were opposite only one pole, or being between two poles, were nearer to one than the other, this effect would cause its repulsion. Still, it cannot account for the whole amount of the repulsion observed alike with copper as with bismuth (2295.), because the currents are of but momentary duration, and the repulsion due to them would cease with them. They do, however, cause a brief repulsive effort, to which is chiefly due the first part of the peculiar effect.

2335. For if the copper bar, instead of being parallel to the face of the magnetic pole, and therefore at right angles to the resultant of magnetic force, be inclined, forming, for instance, an angle of 45° with the face, then the induced currents will move generally in a plane corresponding more or less to that angle, nearly as they do in the examining helix (2333.), if it be inclined in the same manner. This throws the polar axis of the bar of copper on one side, so that the north polarity is not directly opposed to the north pole of the inducing magnet, and hence the action both of this and the other magnetic pole upon the two polarities of the copper will be to send it further round, or to place it edgeways to the poles, or with its breadth parallel to the magnetic resultant passing through it (2323.): the bar therefore receives an impulse, and the angle of it nearest to the magnet appears to be pulled up towards the magnet. This action of course stops the instant the magnetism of the helix core ceases to rise, and then the motion due to this cause ceases, and the copper is simply subject to the action before described (2295.). At the same time that this twist or small portion of a turn round the point of suspension occurs, the centre of gravity of the whole mass is repelled, and thus I believe all the actions up to this condition of things is accounted for.

2336. Then comes the *revulsion* which occurs upon the cessation of the electric current, and the falling of the magnetism in the core. According to the law of magneto-electric induction, the disappearance of the magnetic force will induce brief currents in the copper bar (28.), but in the contrary direction to those induced in the first instance; and therefore the virtual magnetic pole belonging to the copper for the moment, which is nearest the north end of the electro-magnet, will be a south pole; and that which is furthest from the same pole of the magnet will be a north pole. Hence will arise an exertion of force on the bar tending to turn it round its centre of suspension in the contrary direction to that which occurred before, and hence the apparent revulsion; for the angle nearest the magnetic pole will recede from it, the broad face (2323.) or length (2315.) of the bar will come round and face towards the magnet, and an action the reverse in every respect of the first action will take place, except that whereas the motion was then only a few degrees, now it may extend to two or three revolutions.

2337. The cause of this difference is very obvious. In the first instance, the bar of copper was moving under influences powerfully tending to retard and stop it (2329.); in the second case these influences are gone, and the bar revolves freely with a force proportionate to the power exerted by the magnet upon the currents induced by its own action.

2338. Even when the copper is of such form as not to give the oblique resultant of magnetic action from the currents induced in it, when, for instance, it is a cube or a sphere, still the effect of the action described above is evident (2325.). When a plate of copper about three-fourths of an inch in thickness, and weighing two pounds, was sustained upon some loose blocks of wood and placed about 0·1 of an inch from the face of the magnetic pole, it was repelled and held off a certain distance upon the making and continuing of electric contact at the battery; and when the battery current was stopped, it returned towards the pole; but the return was much more powerful than that due to gravity alone (as was ascertained by an experiment), the plate being at that moment actually *attracted*, as well as tending by gravitation towards the magnet, so that it gave a strong tap against it.

2339. Such is, I believe, the explanation of the peculiar phenomena presented by copper in the magnetic field; and the reason why they appear with this metal and not with bismuth or heavy glass, is almost certainly to be found in its high electro-conducting power, which permits the formation of currents in it by inductive forces, that cannot produce the same in a corresponding degree in bismuth, and of course not at all in heavy glass.

2340. Any ordinary magnetism due to metals by virtue of their inherent power, or the presence of small portions of the magnetic metals in them, must oppose the development of the results I have been describing; and hence metals not of absolute purity cannot be compared with each other in this respect. I have, nevertheless, observed the same phenomena in other metals; and as far as regards the sluggishness of rotatory motion, traced it even into bismuth. The following are the metals which have presented the phenomena in a greater or smaller degree:—

Copper.
Silver.
Gold.
Zinc.
Cadmium.
Tin.
Mercury.
Platinum.
Palladium.
Lead.
Antimony.
Bismuth.

2341. The accordance of these phenomena with the beautiful discovery of Arago[*], with the results of the experiments of Herschel and Babbage[†], and with my own former inquiries (81.)[‡], are very evident. Whether the effect obtained by Ampère, with his copper cylinder and a helix[§], was of this nature, I cannot judge, inasmuch as the circumstances of the experiment and the energy of the apparatus are not sufficiently stated; but it probably may have been.

2342. As, because of other duties, three or four weeks may elapse before I shall be able to complete the verification of certain experiments and conclusions, I submit at once these results to the attention of the Royal Society, and will shortly embody the account of the action of magnets on magnetic metals, their action on gases and vapours, and the general considerations in another series of these Researches.

Royal Institution,
Nov. 27, 1845.

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[*] Annales de Chimie, xxvii. 363; xxviii. 325; xxxii. 213. I am very glad to refer here to the Comptes Rendus of June 9, 1845, where it appears that it was M. Arago who first obtained his peculiar results by the use of electro- as well as common magnets.

[†] Philosophical Transactions, 1825, p. 467.

[‡] Ibid. 1832, p. 146.

[§] Bibliothèque Universelle, xxi. p. 48.

III. *Experimental Researches in Electricity.—Twenty-first Series.*

By Michael Faraday, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Cor. Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, &c. &c.*

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§ 27. *On new magnetic actions, and on the magnetic condition of all matter—continued.* ¶ v. *Action of magnets on the magnetic metals and their compounds.* ¶ vi. *Action of magnets on air and gases.* ¶ vii. *General considerations.*

¶ v. *Action of magnets on the magnetic metals and their compounds.*

2343. THE magnetic characters of iron, nickel and cobalt, are well known; and also the fact that at certain temperatures they lose their usual property and become, to ordinary test and observation, non-magnetic; then entering into the list of diamagnetic bodies and acting in like manner with them. Closer investigation, however, has shown me that they are still very different to other bodies, and that though inactive when hot, on common magnets or to common tests, they are not so absolutely, but retain a certain amount of magnetic power whatever their temperature; and also that this power is the same in character with that which they ordinarily possess.

2344. A piece of iron wire, about one inch long and 0·05 of an inch in diameter, being thoroughly cleaned, was suspended at the middle by a fine platinum wire connected with the suspending thread (2249.) so as to swing between the poles of the electro-magnet. The heat of a spirit-lamp was applied to it, and it soon acquired a temperature which rendered it quite insensible to the presence of a good ordinary magnet, however closely it was approached to the heated iron. The temperature of the iron was then raised considerably higher by adjustment of the flame, and the electro-magnet thrown into action. Immediately the hot iron became magnetic and pointed between the poles. The power was feeble, and in this respect the state of the iron was in striking contrast with that which it had when cold; but in character the force was precisely the same.

2345. The iron was then allowed to fall in temperature slowly so that its assumption of the higher magnetic condition might be observed. The intensity of the force did not appear to increase until the temperature arrived near a certain point, and then as the heat continued to diminish, the iron rapidly, but not instantaneously, acquired its high magnetic power; at which time it could not be kept from the magnet, but flew to it, bending the suspending wire and trembling as it were with magnetic energy as it adhered by one end to the core.

2346. A small bar of nickel was submitted to an experimental examination in the same manner. This metal, as I have shown*, loses its magnetism as respects ordinary tests at a heat below that of boiling oil, and hence it is very well fitted to show whether the magnetic metals can have their power entirely removed by heat or not; and also, whether the disappearance of the whole or greater portion of their power is sudden or gradual. The smallness of the mass to be experimented on assisted much in the determination of the latter point. Upon being heated the nickel soon became indifferent to ordinary magnets; but however high the temperature, still it pointed to and was attracted by the electro-magnet. The power was very feeble, but certain. It was scarcely enough to sustain the weight of the nickel by the magnetic action alone; but was abundantly evident when the metal was supported as described (2344.).

2347. On carefully lowering the temperature of the nickel, it was again found that the transition from one degree of magnetic force to the other was progressive, and not instantaneous. With iron it is difficult to preserve all the parts, either in heating or cooling, so nearly at the same temperature as to be sure that it is not the union of hotter and colder portions which gives the appearance of an intermediate degree of magnetism; but with nickel that is not so difficult, for the progression is more gradual, so that when in cooling the power began to increase, the cooling might be continued some time before the full degree of power came on; at any time in that period the temperature might be slightly raised, and though the power would then diminish a little, it could yet be retained at a degree stronger than the weakest. In fact it was easy to *keep* the nickel at many of the intermediate degrees of power, and thus to remove all doubt of the progressive assumption of the full degree of force.

2348. I have expressed an opinion, founded on the different temperatures at which the magnetic metals appeared to lose their peculiar power†, that all the metals would probably have the same character of magnetism if their temperature could be lowered sufficiently. The facts just described appear to me entirely against such an opinion. The metals which are magnetic retain a portion of their power after the great change has been effected, or in what might be called their diamagnetic state; but the other metals, such as bismuth, tin, &c., present no trace of this power, and therefore are not in the condition of the heated iron, nickel, or cobalt; for in fact whilst these point axially and are attracted, the others point equatorially and are repelled. I therefore hope to be allowed to withdraw the view I then put forth.

2349. I next proceeded to examine the peroxides of iron, and in accordance with the observations of M. Becquerel* and others, found them all, both natural and artificial, possessed of magnetic power at common temperatures. I heated them in tubes but found them still magnetic, suffering *no* diminution of the force by such temperature as I could apply to them.

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* Philosophical Magazine, 1836, vol. viii. p. 179. † Ibid. 177; ibid. 1839, vol. xiv. p. 161.

2350. Different specimens of the oxide of nickel were found to present the same phenomena. They were magnetic both when hot and cold; and that heat should cause no change in this respect is the more striking, because the hot oxide had a temperature given to it far higher than that necessary to produce the great magnetic change in the metal itself (2346.).

2351. The oxide of cobalt also was magnetic, and equally magnetic whether hot or cold. Glass coloured blue by cobalt is magnetic in consequence of the presence of the oxide of that metal, and is so whether hot or cold. In all these cases the degree of power retained was very small compared to that of the pure metal.

2352. Proceeding to the *salts* of iron, I found them magnetic. Clean crystals of the proto-sulphate of iron were attracted and pointed axially very well; so also did the dry salt. As I proceeded I found that every salt and compound containing iron in the basic part was magnetic. To enumerate the different substances subjected to trial would be tedious, the following are selected as illustrations of the variety in kind:—

Protochloride.
Perchloride.
Iodide.
Protosulphate.
Persulphate.
Protophosphate.
Perphosphate.
Nitrate.
Carbonate.
Prussian blue.

2353. Amongst native compounds—

Bog iron ore.
Hæmatite.
Chromate of iron.
Yellow sulphuret of iron.
Arsenical pyrites.
Copper pyrites, and many others were magnetic.

2354. Green bottle-glass is comparatively very magnetic from the iron it contains, and cannot be used as tubes to hold other substances. Crown-glass is magnetic from the same cause. Flint-glass is not magnetic, but points equatorially.

2355. Crystals of the yellow ferro-prussiate of potassa were not magnetic, but were repelled and set equatorially; and such was the case also with red ferro-prussiate.

2356. According to my hopes, even the solutions of the ferruginous salts, whether in water or alcohol, were magnetic. A tube filled with a clear solution of proto- or persulphate of iron, or proto- or perchloride, or tincture of muriate of iron, was attracted by the poles, and pointed very well between them in the axial direction.

2357. These solutions supply a very important means of advancing magnetical investigation, for they present us with the power of making a magnet, which is at the same time liquid, transparent, and within certain limits, adjustible to any degree of strength. Hence the power of examining a magnet optically. Hence also, the capability of placing magnetic portions of matter one within another, and so observing dynamic and other phenomena within magnetic media. In fact, not only may these substances be placed as magnets in the magnetic field, but the field generally may be filled with them, and then other bodies and other magnets examined as to their joint or separate actions in it (2361., &c.).

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* Annales de Chimie, 1827, vol. xxxvi. p. 337. Comptes Rendus, 1845, vol. xx. p. 1708.

2358. In reference to the salts of *nickel* and *cobalt*, pure crystals of the sulphate of nickel were found to be well magnetic, and also pure crystals of sulphate of cobalt. Solutions of the sulphate of nickel, the chloride of nickel, and the chloride of cobalt, were also magnetic. That I might be perfectly safe in these conclusions I applied to Mr. ASKIN of Birmingham, whose power of separating nickel and cobalt from each other and other metals is well known, as also the scale upon which he carries on these operations, and he favoured me with a solution of chloride of nickel, and another of chloride of cobalt perfectly pure, both of which proved to be well magnetic between the poles of my magnet.

2359. Heat applied to any of these magnetic solutions did not diminish or affect their power.

2360. These results with the salts of the magnetic metals conjoin with those before quoted, as tending to show that the non-magnetic metals could not by any change of temperature be rendered magnetic (2398.), but as a class are distinct from iron, nickel, and cobalt; for none of the compounds of the non-magnetic metals show, as yet, any indication of ordinary magnetic force, whereas in respect of these three substances all their compounds possess it.

2361. In illustration of the power which the iron and other similar solutions give in the investigation of magnetic phenomena (2357.), as well as in reference to the general conclusions to be drawn from all the facts described in this paper, I will proceed to describe certain anticipated results which were obtained by the employment of these solutions in the magnetic field.

2362. A clear solution of the proto-sulphate of iron was prepared, in which one ounce of the liquid contained seventy-four grains of the hydrated crystals; a second solution was prepared containing one volume of the former and three volumes of water; a third solution was made of one volume of the stronger solution and fifteen volumes of water. These solutions I will distinguish as Nos. 1, 2, and 3; the proportions of crystals of sulphate of iron in them were respectively as 16, 4, and 1 per cent. nearly. These numbers may, therefore, be taken as representing (generally only (2423.)) the strength of the magnetic part of the liquids.

2363. Tubes like that before described (2279.) were prepared and filled respectively with these solutions, and then hermetically sealed, as little air as possible being left in them. Glasses of the solutions were also prepared, large enough to allow the tubes to move freely in them, and yet of such size and shape as would permit of their being placed between the magnetic poles. In this manner the action of the magnetic forces upon the matter in the tubes could be examined and observed, both when the tubes were in diamagnetic media, as air, water, alcohol, &c., and also in magnetic media, either stronger or weaker in magnetic force than the substances in the tubes.

2364. When these tubes were suspended in air between the poles, they all pointed axially or magnetically, as was to be expected; and with forces apparently proportionate to the strengths of the solutions. When they were immersed in alcohol or water, they also pointed in the same direction; the strongest solution very well, and also the second, but the weakest solution was feeble in its action though very distinct in its character (2422.).

2365. When the tubes, immersed in the different ferruginous solutions, were acted upon, the results were very interesting. The tube No. 1 (the strongest magnetically), when in solution No. 1, had no tendency, under the influence of the magnetic power, to any particular position, but remained wherever it was placed. Being placed in solution No. 2, it pointed well axially, and in solution No. 3 it took the same direction, but with still more power.

2366. The tube No. 2, when in the solution No. 1, pointed equatorially, *i. e.* as heavy glass, bismuth, or a diamagnetic body generally, in air. In solution No. 2 it was indifferent, not pointing either way; and in solution No. 3 it pointed axially, or as a magnetic body. The tube No. 3 containing the weakest solution, pointed equatorially in solutions No. 1 and 2, and not at all in solution No. 3.

2367. Several other ferruginous solutions varying in strength were prepared, and, as a general and constant result, it was found that any tube pointed axially if the solution in it was stronger than the surrounding solution, and equatorially if the tube solution was the weaker of the two.

2368. The tubes were now suspended vertically, so that being in the different solutions they could be brought near to one of the magnetic poles, and employed in place of the indicating cube or sphere of bismuth, or heavy glass (2266.). The constant result was, that when the tube contained a stronger solution than that which surrounded it, it was attracted to the pole, but when its solution was the weaker of the two it was repelled. The latter phenomena were as to appearance in every respect the same as those presented in the repulsion of heavy glass, bismuth, or any other diamagnetic body in air.

2369. Having described these phenomena, I will defer their further consideration until I arrive at the last division of this paper, and proceed to certain results more especially belonging to the present part of these Researches.

2370. As the magnetic metals, iron, nickel and cobalt, present in their compounds substances also distinguished by the possession of magnetic properties (2360.), so it appeared very probable that other metals, of whose magnetic character doubts were entertained, because of the possible presence of iron in the specimens experimented with, might in this way have their magnetic character tested; for it seemed likely, from analogy, that every metal well magnetic *per se*, would be magnetic in its compounds; and, judging from the character of the great class of diamagnetic bodies (2275.), that no magnetic compounds would be obtained of a metal not magnetic of itself. Accordingly I proceeded to apply this kind of test to the combinations of many of the metals, and obtained the following results :—

2371. *Titanium.*—Wollaston has described the magnetic effects of crystals of titanium, expressing at the same time a belief that they are due to iron[*]. I took a specimen of the oxide of titanium, which I believe to be perfectly free from iron, and inclosing it in a tube (2279.), subjected it to the action of the electro-magnet (2246. 2247.). It proved to be freely magnetic. Another specimen obtained from Mr. Johnson, and believed by him to be perfectly free from iron, was also magnetic. Hence I conclude that titanium is truly a magnetic metal.

2372. *Manganese.*—Berthier, as far as I am aware, first announced that this metal was magnetic at very low temperatures[†]. On submitting specimens of the various oxides, which were considered as pure, to the magnetic force, they were all found to be magnetic, especially the protoxide. So were the following compounds of manganese in the pure, dry, or crystallized state :—chloride, sulphate, ammonio-sulphate, phosphate, carbonate, borate ; and also the chloride, nitrate, sulphate, and ammonio-sulphate when in solution. A specimen of the ammonio-sulphate was rendered alkaline by the addition of a little carbonate of ammonia boiled and then carefully crystallized thrice ; after that the crystals and solution of the purified salt were perfectly and well magnetic. I have no doubt, therefore, that manganese is a magnetic metal, as Berthier said. If any opinion may be drawn concerning the magnetic force of the metal from the degree of magnetism of the compounds, I should expect that manganese possesses considerable power of this kind when at a sufficiently low temperature[‡].

2373. *Cerium.*—I am not aware that cerium has as yet been classed with the magnetic metals. Having made experiments with the hydrated protoxide, the carbonate, and the chloride of this metal, and also with the double sulphate of the oxide and potassa prepared with great care, I found them all magnetic; and those that are soluble are magnetic in the state of solution. Hence, as the compounds are undoubtedly magnetic, there is every reason to believe that cerium also is a magnetic metal (2370.).

2374. *Chromium.*—The magnetic phenomena of chromium compounds are very interesting. Portions of the chromate and the bichromate of potassa were purified by three careful crystallizations each ; part of the bichromate was heated in a platinum crucible, until the second equivalent of chromic acid was converted into the crystallized oxide, and this being washed out and dried was found to be well magnetic. So were all the other specimens of oxide of chromium which were examined.

A specimen of Warrington's chromic acid was found to be very feebly magnetic.

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[*] Philosophical Transactions, 1823, p. 400.

[†] Traité des Essais par la Voie Sèche, tome i. p. 582. Philosophical Magazine, 1845, vol. xxvii. p. 2.

[‡] Philosophical Magazine, 1845, vol. xxvii. p. 2.

2375. Chromate of lead, when subjected to the magnet, pointed equatorially and was repelled. Such was the case also with crystals of the chromate of potassa. Crystals of the bichromate, however, did not act thus; for if in any way affected they were in the least degree magnetic, showing the influence of the increased proportion of chromic acid. Solutions of either salt pointed well equatorially and were repelled; thus showing the diamagnetic influence of the water present (2422.).

2376. As just stated, a solution of the bichromate contained in a tube, pointed equatorially and was repelled; but if the same solution had a little alcohol added to it, and also some pure muriatic or sulphuric acid, and were then heated for a few minutes to reduce the chromic acid to the state of oxide or chloride, then, on being returned to the tube and subjected to the magnet, it was found strongly magnetic.

2377. I think it has before been said that chromium is a magnetic metal; as these results have been obtained with its pure compounds, there is no longer any doubt on my mind that such is the case.

2378. *Lead.*—The compounds of lead point equatorially and are repelled. The substances tried were the chloride, iodide, sulphuret, nitrate, sulphate, phosphate, carbonate, protoxide fused, and the acetate. A portion of very carefully crystallized nitrate being dissolved was precipitated by pure zinc, and the lead obtained washed with dilute nitric acid, to remove subsalts. Such lead was free from magnetism, and therefore the metal ranks in the diamagnetic class, both directly and by its compounds. Lead usually appears to be magnetic, and it is not very easy to obtain the metal in the pure diamagnetic state.

2379. *Platinum.*—I have, as yet, found no wrought specimens of this metal free from magnetism, not even those prepared by Dr. WOLLASTON himself, and left with the Royal Society. Specimens of the purest platinum obtained from Mr. JOHNSON were also found to be slightly magnetic.

2380. Clean platinum foil and cuttings were dissolved in pure nitro-muriatic acid, and the solution evaporated to dryness. Both the solution and the dry chloride pointed equatorially and were repelled by the magnet. A part of the chloride being dissolved and rendered acid, was precipitated by an acid solution of muriate of ammonia, and the ammonio-chloride of platinum washed and dried: it also, at the magnet, pointed equatorially and was repelled. A portion of this ammonio-chloride, decomposed in a flint-glass tube by heat, gave spongy platinum, which being pressed together into a cake, pointed *axially* and was attracted at the side of the magnetic pole, being magnetic.

2381. At present I believe that platinum is as a metal magnetic, though very slightly so; and that in the compounds, the change of state and the presence of other substances having the diamagnetic character, are sufficient to cover this property and make the whole compound diamagnetic (2422.).

2382. *Palladium.*—All the palladium in the possession of the Royal Society, prepared by Dr. WOLLASTON, amounting to ten ingots and rolled plates, is magnetic.

Specimens of the metal from Mr. Johnson, considered as pure, were also slightly magnetic. The chloride, the ammonio-bichloride, and the cyanuret of palladium, pointed equatorially and were repelled by the magnet. The same cyanuret, reduced by heat either in open platinum vessels or in close glass tubes, gave palladium possessing a feeble degree of magnetic property. Some of Wollaston's palladium was dissolved in pure nitromuriatic acid, and the solution slowly acted upon by pure zinc, free from iron, and not magnetic. Five successive portions of the precipitated metal were collected, and *all* were *magnetic*. Ammonio-bichloride of palladium was prepared from the same solution by pure acid muriate of ammonia, and digested in nitromuriatic acid. The salt itself was repelled, being diamagnetic; but when reduced by heat in glass tubes, or in Berlin capsules, the palladium obtained was magnetic. From the result of all the experiments, I believe the metal to be feebly but truly magnetic.

2383. *Arsenic.*—This metal required very particular examination, and even when carefully sublimed twice or thrice in succession, presented appearances which sometimes made me class it with the magnetic, and at other times with the diamagnetic bodies. On the whole, I incline to believe that it belongs to the latter series of substances, being only in a very small degree removed from the zero or medium point. Pure white arsenic points freely in an equatorial direction, and is repelled by a magnetic pole.

2384. In reference to the pointing of short bars between magnetic poles exposing large flat faces, I ought to observe, that such bars will sometimes point axially and seem to be magnetic when they do not belong to that class, and are repelled by a single pole. The cause of this effect has been already given (2298. 2299.), and is obviated by the use of poles having wedge-shaped or conical terminations.

2385. *Osmium.*—Osmic acid from Mr. Johnson, in fine transparent crystals, was clearly diamagnetic, being repelled. Specimens of the metal and of the protoxide were both slightly magnetic. The protoxide had been obtained by the action of alcohol on a solution of osmic acid which had twice been distilled with water, and the metal was believed to be perfectly free from other substances. Probably, therefore, osmium belongs to the magnetic class.

2386. *Iridium.*—Mr. Johnson supplied me with several preparations of iridium. The oxide, chloride, and ammonio-chloride were magnetic; and so was a sample of the metal. One specimen of the metal, which seemed to be very pure, was scarcely at all magnetic; and on the whole, I incline to believe that iridium does not stand in the magnetic class.

2387. *Rhodium.*—A well-fused specimen of this metal, prepared by Dr. Wollaston, was magnetic; but crystals of the chloride and the sodio-chloride of rhodium prepared by the same philosopher, and others also from Mr. Johnson, were not magnetic, but pointed well equatorially. I conclude, therefore, that the metal is probably not magnetic, or if magnetic, is but little removed from the zero point.

2388. *Uranium.*—Peroxide of this metal was obtained not magnetic; protoxide very slightly magnetic: I have set the metal for the present in the diamagnetic class.

2389. *Tungsten.*—The oxide of this metal, and also the acid, were submitted to examination, and found to point well equatorially. The acid was distinctly repelled by a single magnetic pole; the oxide appeared nearly neutral. Hence I have, for the present, considered tungsten as a diamagnetic metal.

2390. *Silver* is not magnetic (2291.), nor its compounds.

2391. *Antimony* is not magnetic (2291.), nor its compounds.

2392. *Bismuth* is not magnetic (2291.), nor its compounds.

Having tried many of the compounds of each of these three metals, I thought it well to record the accordance existing between them and their metallic bases (2370.).

2393. *Sodium.*—A fine large globule, equal to half a cubic inch in size, was well repelled, and is therefore diamagnetic.

2394. *Magnesium.*—None of the compounds or salts of this base are magnetic.

2395. Calcium.
Strontium.
Barium.
Sodium.
Potassium.
Ammonia.

None of the compounds or salts of these substances are magnetic.

2396. From the characters, therefore, of the compounds, as well as from direct evidence in respect of some of the metals, it would appear that, besides iron, nickel, and cobalt, the following are also magnetic; namely, titanium, manganese, cerium, chromium, palladium, platinum. It is, however, very probable that there may be metals possessing distinct magnetic power, yet in so slight a degree as, like platinum and palladium, not to exhibit in their compounds any sensible trace of it. Such may be the case with tungsten, uranium, rhodium, &c.

2397. I have heated several of the diamagnetic metals, even up to their fusing-points, but have not been able to observe any change, either in the character or degree of their magnetic relations.

2398. Perhaps the cooling of some of the metals, whose compounds, like those of iron, nickel and cobalt, are magnetic, might develope in them a much higher degree of force than any which they have as yet been known to possess. Manganese, chromium, cerium, titanium, are metals of much interest in this point of view. Osmium, iridium, rhodium and uranium, ought to be subjected with them to the same trial.

2399. The following is an attempt to arrange some of the metals in order, as respects their relation to magnetic force. The 0° or medium point is supposed to be the condition of a metal or substance indifferent to the magnetic force as respects attraction or repulsion in air or space. The further substances are placed from this point, the more distinctive are they as regards their attraction or repulsion by the magnet. Nevertheless this order may, very probably, be found inaccurate by more careful observation.

Diamagnetic.
Bismuth.
Antimony.
Zinc.
Tin.
Cadmium.
Sodium.
Mercury.
Lead.
Silver.
Copper.
Gold.
Arsenic.
Uranium.
Rhodium.
Iridium.
Tungsten.

Magnetic.
Iron.
Nickel.
Cobalt.
Manganese.
Chromium.
Cerium.
Titanium.
Palladium.
Platinum.
Osmium.

0°.

¶ vi. *Action of magnets on air and gases.*

2400. It was impossible to advance in an experimental investigation of the kind now described, without having the mind impressed with various theoretical views of the mode of action of the bodies producing the phenomena. In the passing consideration of these views, the apparently middle condition which *air* held between magnetic and diamagnetic substances was of the utmost interest, and led to many experiments upon its probable influence, which I will now proceed briefly to describe.

2401. A thin flint-glass tube, in which common air was hermetically enclosed, was placed between the magnetic poles (2249.) surrounded by air, and the effect of the magnetic force observed upon it. There was a very feeble tendency of the tube to an equatorial position, due to the substance of the tube in which the air was enclosed.

2402. The air was then withdrawn from around the tube more or less, and at last up to the highest amount which a good air-pump would effect; but whatever the degree of rarefaction, the tube of air still seemed to be affected exactly in the same manner as if surrounded by air of its own density.

2403. I then surrounded the air-tube with hydrogen and carbonic acid in succession; but in both these, and in each of them at different degrees of rarefaction, the tube of air remained as indifferent as before.

2404. Hence there appears to be no sensible distinction between dense or rare air; or, as far as these experiments go, between one gas or vapour and another.

2405. As it did not seem at all unlikely that the equatorial and axial set of bodies, or their repulsions and attractions, might depend upon converse actions of the media by which they were surrounded (2361.), so I proceeded to examine what would occur with diamagnetic substances, when the air or gas which surrounded them was changed in its density or nature, or what would happen to air itself when surrounded by these substances.

2406. The air-tube (2401.) was suspended horizontally in water (being retained below the surface by a cube of bismuth attached to it, just beneath the point of suspension, which therefore could have no power of giving it direction); it was then subjected to the magnetic forces, and immediately pointed well in an axial direction, or as a magnet would have done. Being brought near to one pole it moved, on the supervention of the magnetic force, appearing as if *attracted* after the manner of a magnetic body; and this continued as long as the magnetic force was sustained in action.

2407. The air-tube was in like manner subjected to the action of the magnetic force, when surrounded by alcohol, and also by oil of turpentine, with precisely the same results as in water. In all these cases the action of air in the fluids was precisely the same as the action of a magnetic body in air. The air-tube was subjected to the action of the magnet even when under the surface of mercury, and here also it pointed axially.

2408. In order to extend the experimental relations of air and gases, I proceeded to place substances of the diamagnetic class in them. Thus, the bar of heavy glass (2253.) was suspended in a jar of air, and then the air about it more or less rarefied, but, as before, in the case of the air-tube (2402.), alterations of this kind produced no effect. Whether the bar were in air at the ordinary pressure, or as rare as the pump could render it, it still pointed equatorially, and apparently always with the same degree of force.

2409. The bar of bismuth (2296.) was suspended in the jar, and the same alteration in the density of the air made as before; but this caused no difference in the action of the bismuth, either in kind or degree. Carbonic acid and hydrogen gases were then introduced in succession into the jar, and these also were employed in different degrees of rarefaction, but the results were the same; no change took place in the action on the bismuth.

2410. A bismuth cube was suspended in air and gases at ordinary pressure, and also rarefied as much as could be, and under these circumstances it was brought near the magnetic pole and its repulsion observed; its action was in all these cases precisely the same as in the atmosphere.

2411. The perpendicular copper bar (2323.) was suspended near the magnetic pole *in vacuo*, but its set, sluggish movements and revulsion, were just the same as before in air (2324.).

2412. The following preparations in tubes (2401.), namely, a vacuum, air, hydrogen, carbonic acid gas, sulphurous acid gas, and vapour of ether, were surrounded by water, and then subjected to the magnetic force; they all pointed axially, and, as far as I could perceive, with equal force. Being placed in alcohol the same effect occurred.

2413. The same preparations being surrounded by air, or by carbonic acid gas, all set equatorially.

2414. The axial position of the tubes in the liquid (2412.) depends, doubtless, upon the relation of the contents of the tube to the surrounding medium; for as far as the matter of the tube is concerned, it alone would have tended to give the equatorial position. In the following succeeding experiments (2413.), where the tubes of gases were in surrounding gases, the equatorial position is due to this effect of the glass of the tube; and that it should produce its constant feeble effect, undisturbed by all the variations of the gases and vapours, is a proof how like and how indifferent these are one to the other.

2415. I suspended a tube of liquid sulphurous acid in gaseous sulphurous acid; when under the magnetic influence, the liquid pointed well equatorially. I surrounded liquid nitrous acid by gaseous nitrous acid; the liquid pointed well equatorially. I placed liquid ether in the vapour of ether; the former pointed equatorially. Upon suspending the tube of vapour of ether in liquid ether, the vapour pointed axially.

2416. In every kind of trial, therefore, and in every form of experiment, the gases and vapours still occupy a medium position between the magnetic and the diamagnetic classes. Further, whatever the chemical or other properties of the substances, however different in their specific gravity, or however varied in their own degree of rarefaction, they all become alike in their magnetic relation, and apparently equivalent to a perfect vacuum. Bodies which are very marked as diamagnetic substances, immediately lose all traces of this character when they become vaporous (2415.). It would be exceedingly interesting to know whether a body from the magnetic class, as chloride of iron, would undergo the same change.

¶ vii. *General considerations.*

2417. Such are the facts which, in addition to those presented by the phenomena of light, establish a magnetic action or condition of matter new to our knowledge. Under this action, an elongated portion of such matter usually (2253. 2384.) places itself at right angles to the lines of magnetic force; this result may be resolved into the simpler one of repulsion of the matter by either magnetic pole. The set of the elongated portion, or the repulsion of the whole mass, continues as long as the magnetic force is sustained, and ceases with its cessation.

2418. By the exertion of this new condition of force, the body moved may pass either *along* the magnetic lines or *across* them, and it may move along or across them in either or any direction. So that two portions of matter, simultaneously subject to this power, may be made to approach each other as if they were mutually attracted, or recede as if mutually repelled. All the phenomena resolve themselves into this, that a portion of such matter, when under magnetic action, tends to move from stronger to weaker places or points of force. When the substance is surrounded by lines of magnetic force of equal power on all sides, it does not tend to move, and is then in marked contradistinction with a linear current of electricity under the same circumstances.

2419. This condition and effect is new, not *only* as it respects the exertion of power by a magnet over bodies previously supposed to be indifferent to its influence, but is *new* as a magnetic action, presenting us with a second mode in which the magnetic power can exert its influence. These two modes are in the same general antithetical relation to each other as positive and negative in electricity, or as northness and southness in polarity, or as the lines of electric and magnetic force in magneto-electricity; and the diamagnetic phenomena are the more important, because they extend largely, and in a new direction, that character of duality which the magnetic force already, in a certain degree, was known to possess.

2420. All matter appears to be subject to the magnetic force as universally as it is to the gravitating, the electric and the chemical or cohesive forces; for that which is not affected by it in the manner of ordinary magnetic action, is affected in the manner I have now described; the matter possessing for the time the solid or fluid state. Hence substances appear to arrange themselves into two great divisions, the magnetic, and that which I have called the diamagnetic classes; and between these classes the contrast is so great and direct, though varying in degree, that where a substance from the one class will be attracted, a body from the other will be repelled; and where a bar of the one will assume a certain position, a bar of the other will acquire a position at right angles to it.

2421. As yet I have not found a single solid or fluid body, not being a mixture, that is perfectly neutral in relation to the two lists; *i. e.* that is neither attracted nor repelled in air. It would probably be important to the consideration of magnetic action, to know if there were any natural simple substance possessing this condition in the solid or fluid state. Of compound or mixed bodies there may be many; and as it may be important to the advancement of experimental investigation, I will describe the principles on which such a substance was prepared when required for use as a circumambient medium.

2422. It is manifest that the properties of magnetic and diamagnetic bodies are in opposition as respects their dynamic effects; and, therefore, that by a due mixture of bodies from each class, a substance having any intermediate degree of the property of either may be obtained. Protosulphate of iron belongs to the magnetic, and water to the diamagnetic class; and using these substances, I found it easy to make a solution which was neither attracted nor repelled, nor pointed when in air. Such a solution pointed axially when surrounded by water. If made somewhat weaker in respect of the iron, it would point axially in water but equatorially in air; and it could be made to pass more and more into the magnetic or the diamagnetic class by the addition of more sulphate of iron or more water.

2423. Thus a *fluid* medium was obtained, which, practically, as far as I could perceive, had every magnetic character and effect of a gas, and even of a vacuum; and as we possess both magnetic and diamagnetic glass (2354.), it is evidently possible to prepare a *solid* substance possessing the same neutral magnetic character.

2424. The endeavour to form a general list of substances in the present imperfect state of our knowledge would be very premature: the one below is given therefore only for the purpose of conveying an idea of the singular association under which bodies come in relation to magnetic force, and for the purpose of general reference hereafter:—

Iron.
Nickel.
Cobalt.
Manganese.
Palladium.
Crown-glass.
Platinum.
Osmium.
0° Air and vacuum.
Arsenic.
Ether.
Alcohol.
Gold.
Water.
Mercury.
Flint-glass.
Tin.
Heavy glass.
Antimony.
Phosphorus.
Bismuth.

2425. It is very interesting to observe that metals are the substances which stand at the extremities of the list, being of all bodies those which are most powerfully opposed to each other in their magnetic condition. It is also a very remarkable circumstance that these differences and departures from the medium condition, are in the metals at the two extremes, iron and bismuth, associated with a small conducting power for electricity. At the same time the *contrast* between these metals, as to their fibrous and granular state, their malleable and brittle character, will press upon the mind whilst contemplating the possible condition of their molecules when subjected to magnetic force.

2426. In reference to the metals, as well as the diamagnetics not of that class (2286.), it is satisfactory to have such an answer to the opinion that all bodies are magnetic as iron, as does not consist in a mere negation of that which is affirmed, but in proofs that they are in a different and opposed state, and are able to counteract a very considerable degree of magnetic force (2448.).

2427. As already stated, the magnetic force is so strikingly distinct in its action upon bodies of the magnetic and the diamagnetic class, that when it causes the attraction of the one it produces the repulsion of the other; and this we cannot help referring, in some way, to an action upon the molecules or the mass of the substances acted upon, by which they are thrown into different conditions and affected accordingly. In that point of view it is very striking to compare the results with those which are presented to us by a polarized ray, especially as then a remarkable difference comes into view; for if transparent bodies be taken from the two classes, as for instance, heavy glass or water from the diamagnetic, and a piece of green glass or a solution of green vitriol from the magnetic class, then a given line of magnetic force will cause the repulsion of one and the attraction of the other; but this same line of force which thus affects the particles so differently, affects the polarized ray when passing through them precisely in the *same* manner in both cases; for the two bodies cause its rotation in the *same* direction (2160. 2199. 2224.).

2428. This consideration becomes even more important when we connect it with the diamagnetic and the optical properties of bodies which rotate a polarized ray. Thus the iron solution and a piece of quartz, having the power to rotate a ray, point by the influence of the *same* line of magnetic force, the one axially and the other equatorially; but the rotation which is impressed on a ray of light by these two bodies, as far as they are under the influence of the same magnetic force, is the *same* for both. Further, this rotation is quite independent of, and quite unlike that of the quartz in a most important point; for the quartz by itself can only rotate the ray in one direction, but under the influence of the magnetic force it can rotate it both to the right and left, according to the course of the ray (2231. 2232.). Or, if two pieces of quartz (or two tubes of oil of turpentine) be taken which can rotate the ray *different* ways, the further rotative force manifested by them when under the dominion of the magnetism is always the *same* way; and the direction of that way may be made either to the right or left in either crystal of quartz. All this time the *contrast* between the quartz as a diamagnetic, and the solution of iron as a magnetic body remains undisturbed. Certain considerations regarding the character of a ray, arising from these contrasts, press strongly on my mind, which, when I have had time to submit them to further experiment, I hope to present to the Society.

2429. Theoretically, an explanation of the movements of the diamagnetic bodies, and all the dynamic phenomena consequent upon the actions of magnets on them, might be offered in the supposition that magnetic induction caused in them a contrary state to that which it produced in magnetic matter; *i. e.* that if a particle of each kind of matter were placed in the magnetic field both would become magnetic, and each would have its axis parallel to the resultant of magnetic force passing through it; but the particle of magnetic matter would have its north and south poles opposite, or facing towards the contrary poles of the inducing magnet, whereas with the diamagnetic particles the reverse would be the case; and hence would result approximation in the one substance, recession in the other.

2430. Upon Ampère's theory, this view would be equivalent to the supposition, that as currents are induced in iron and magnetics parallel to those existing in the inducing magnet or battery wire; so in bismuth, heavy glass and diamagnetic bodies, the currents induced are in the contrary direction. This would make the currents in diamagnetics the same in direction as those which are induced in diamagnetic conductors at the *commencement* of the inducing current; and those in magnetic bodies the same as those produced at the *cessation* of the same inducing current. No difficulty would occur as respects non-conducting magnetic and diamagnetic substances, because the hypothetical currents are supposed to exist not in the mass, but round the particles of the matter.

2431. As far as experiment yet bears upon such a notion, we may observe, that the known inductive effects upon masses of magnetic and diamagnetic metals *are the same.* If a straight rod of iron be carried across magnetic lines of force, or if it, or a helix of iron rods or wire, be held near a magnet, as the power in it rises electric currents are induced, which move through the bars or helix in certain determinate directions (38. 114., &c.). If a bar or a helix of bismuth be employed under the same circumstances the currents are again induced, and precisely in the same direction as in the iron, so that here no difference occurs in the direction of the induced current, and not very much in its force, nothing like so much indeed as between the current induced in either of these metals and a metal taken from near the neutral point (2399.). Still there is this difference remaining between the conditions of the experiment and the hypothetical case; that in the former the induction is manifested by currents in the masses, whilst in the latter, *i.e.* in the special magnetic and diamagnetic effects, the currents, if they exist, are probably about the particles of the matter.

2432. The magnetic relation of aëriform bodies is exceedingly remarkable. That oxygen or nitrogen gas should stand in a position intermediate between the magnetic and diamagnetic classes; that it should occupy the place which *no* solid or liquid element can take; that it should show no change in its relations by rarefaction to any possible degree, or even when the space it occupies passes into a vacuum; that it should be the same magnetically with any other gas or vapour; that it should not take its place at one end but in the very middle of the great series of bodies; and that all gases or vapours should be alike, from the rarest state of hydrogen to the densest state of carbonic acid, sulphurous acid, or ether vapour, are points so striking, as to persuade one at once that air must have a great and perhaps an active part to play in the physical and terrestrial arrangement of magnetic forces.

2433. At one time I looked to air and gases as the bodies which, allowing attenuation of their substance without addition, would permit of the observation of corresponding variations in their magnetic properties; but now all such power by rarefaction appears to be taken away; and though it is easy to prepare a liquid medium which shall act with other bodies as air does (2422.), still it is not truly in the same relation to them; neither does it allow of dilution, for to add water or any such substance is to add to the diamagnetic power of the liquid; and, if it were possible to convert it into vapour and so dilute it by heat, it would pass into the class of gases and be magnetically undistinguishable from the rest.

2434. It is also very remarkable to observe the apparent disappearance of magnetic condition and effect when bodies assume the vaporous or gaseous state, comparing it at the same time with the similar relation to light; for as yet no gas or vapour has been made to show any magnetic influence over the polarized ray, even by the use of powers far more than enough to manifest such action freely in liquid and solid bodies.

2435. Whether the negative results obtained by the use of gases and vapours depend upon the smaller quantity of matter in a given volume, or whether they are direct consequences of the altered physical condition of the substance, is a point of very great importance to the theory of magnetism. I have imagined, in elucidation of the subject, an experiment with one of M. Cagniard de la Tour's ether tubes, but expect to find great difficulty in carrying it into execution, chiefly on account of the strength, and therefore the mass of the tube necessary to resist the expansion of the imprisoned heated ether.

2436. The remarkable condition of air and its relation to bodies taken from the magnetic and the diamagnetic classes, causes it to point equatorially in the former and axially in the latter. Or, if the experiment presents its results under the form of attraction and repulsion, the air moves as if repelled in a magnetic medium and attracted in a medium from the diamagnetic class. Hence it seems as if the air were magnetic when compared with diamagnetic bodies, and of the latter class when compared to magnetic bodies.

2437. This result I have considered as explained by the assumption that bismuth and its congeners are absolutely repelled by the magnetic poles, and would, if there were nothing else concerned in the phenomenon than the magnet and the bismuth, be equally repelled. So also with the iron and its similars, the attraction has been assumed as a direct result of the mutual action of them and the magnets; further, these actions have been admitted as sufficient to account for the pointing of the air both axially and equatorially, as also for its apparent attraction and repulsion; the effect in these cases being considered as due to the travelling of the air to those positions which the magnetic or diamagnetic bodies tended to leave.

2438. The effects with air are, however, in these results precisely the same as those which were obtained with the solutions of iron of various strength (2365.), where *all* the bodies belonged to the magnetic class, and where the effect was evidently due to the greater or smaller degree of magnetic power possessed by the solutions. A weak solution in a stronger pointed equatorially and was repelled like a diamagnetic, not because it did not tend by attraction to an axial position, but because it tended to that position with less force than the matter around it; so the question will enter the mind, whether the diamagnetics, when in air, are repelled and tend to the equatorial position for any other reason, than that the air is more magnetic than they are, and tends to occupy the axial space. It is easy to perceive that if all bodies were magnetic in different degrees, forming one great series from end to end, with air in the middle of the series, the effects would take place as they do actually occur. Any body from the middle part of the series would point equatorially in the bodies above it and axially in those beneath it; for the matter which, like bismuth, goes from a strong to a weak point of action, may do so only because that substance, which is already at the place of weak action, tends to come to the place where the action is strong; just as in electrical induction the bodies best fitted to carry on the force are drawn into the shortest line of action. And so air in water, or even under mercury, is, or appears to be, drawn towards the magnetic pole.

2439. But if this were the true view, and air had such power amongst other bodies as to stand in the midst of them, then one would be led to expect that rarefaction of the air would affect its place, rendering it, perhaps, more diamagnetic, or at all events altering its situation in the list. If such were the case, bodies that set equatorially in it in one state of density, would, as it varied, change their position, and at last set axially: but this they do not do; and whether the rarefied air be compared with the magnetic or the diamagnetic class, or even with dense air, it keeps its place.

2440. Such a view also would make mere space magnetic, and precisely to the same degree as air and gases. Now though it may very well be, that space, air and gases, have the same general relation to magnetic force, it seems to me a great additional assumption to suppose that they are all absolutely magnetic, and in the midst of a series of bodies, rather than to suppose that they are in a normal or zero state. For the present, therefore, I incline to the former view, and consequently to the opinion that diamagnetics have a specific action antithetically distinct from ordinary magnetic action, and have thus presented us with a magnetic property new to our knowledge.

2441. The amount of this power in diamagnetic substances seems to be very small, when estimated by its dynamic effect, but the motion which it can generate is perhaps not the most striking measure of its force; and it is probable that when its nature is more intimately known to us, other effects produced by it and other indicators and measurers of its powers, than those so imperfectly made known in this paper, will come to our knowledge, and perhaps even new classes of phenomena will serve to make it manifest and indicate its operation. It is very striking to observe the feeble condition of a helix when alone, and the astonishing force which, in giving and receiving, it manifests by association with a piece of soft iron. So also here we may hope for some analogous development of this element of power, so new as yet to our experience. It cannot for a moment be supposed, that, being given to natural bodies, it is either superfluous or insufficient, or unnecessary. It doubtless has its appointed office, and that, one which relates to the whole mass of the globe; and it is probably because of its relation to the whole earth, that its amount is necessarily so small (so to speak) in the portions of matter which we handle and subject to experiment. And small as it is, how vastly greater is this force, even in dynamic results, than the mighty power of gravitation, for instance, which binds the whole universe together, when manifested by masses of matter of equal magnitude!

2442. With a full conviction that the uses of this power in nature will be developed hereafter, and that they will prove, as all other natural results of force do, not merely important but essential, I will venture a few hasty observations.

2443. Matter cannot thus be affected by the magnetic forces without being itself concerned in the phenomenon, and exerting in turn a due amount of influence upon the magnetic force. It requires mere observation to be satisfied that when a magnet is acting upon a piece of soft iron, the iron itself, by the condition which its particles assume, carries on the force to distant points, giving it direction and concentration in a manner most striking. So also here the condition which the particles of intervening diamagnetics acquire, may be the very condition which carries on and causes the transfer of force through them. In former papers (1161, &c.)* I proposed a theory of electrical induction founded on the action of contiguous particles, with which I am now even more content than at the time of its proposition: and I then ventured to suggest that probably the lateral action of electrical currents which is equivalent to electrodynamic or *magnetic* action, was also conveyed onwards in a similar manner (1663. 1710. 1729. 1735.). At that time I could discover no peculiar condition of the intervening or diamagnetic matter; but now that we are able to distinguish such an action, so *like* in its nature in bodies so *unlike* in theirs, and by that so like in character to the manner in which the magnetic force pervades all kinds of bodies, being at the same time as universal in its presence as it is in its action; now that diamagnetics are shown not to be indifferent bodies, I feel still more confidence in repeating the same suggestion, and asking whether it may not be by the action of the contiguous or next succeeding particles that the magnetic force is carried onwards, and whether the peculiar condition acquired by diamagnetics when subject to magnetic action, is not that condition by which such propagation of the force is affected?

2444. Whichever view we take of solid and liquid substances, whether as forming two lists, or one great magnetic class (2424. 2437.), it will not, as far as I can perceive, affect the question. They are all subject to the influence of the magnetic lines of force passing through them, and the virtual difference in property and character between any two substances taken from different places in the list (2424.) will be the same; for it is the differential relation of the two which governs their mutual effects.

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* Philosophical Transactions, 1838, Part I.

2445. It is that group which includes air, gases, vapours, and even a vacuum which presents any difficulty to the mind; but here there is such a wonderful change in the physical constitution of the bodies, and such high powers in some respects are retained by them, whilst others seem to vanish, that we might almost expect some peculiar condition to be assumed in regard to a power so universal as the magnetic force. Electric induction being an action through distance, is varied enough amongst solid and liquid bodies; but, when it comes to be exerted in air or gases, where it most manifestly exists, it is alike in amount in all (1292.); neither does it vary in degree in air however rare or dense it may be (1284.). Now magnetic action may be considered as a mere function of electric force, and if it should be found to correspond with the latter in this particular relation to air, gases, &c., it would not excite in my mind any surprise.

2446. In reference to the manner in which it is possible for electric force, either static or dynamic, to be transferred from particle to particle when they are at a distance from each other, or across a vacuum, I have nothing to add to what I have said before (1614, &c.). The supposition that such can take place, can present nothing startling to the mind of those who have endeavoured to comprehend the radiation and the conduction of heat under one principle of action.

2447. When we consider the magnetic condition of the earth as a whole, without reference to its possible relation to the sun, and reflect upon the enormous amount of diamagnetic matters which, to our knowledge, forms its crust; and when we remember that magnetic curves of a certain amount of force and universal in their presence, are passing through these matters and keeping them constantly in that state of tension, and therefore of action, which I hope successfully to have developed, we cannot doubt but that some great purpose of utility to the system, and us its inhabitants, is thereby fulfilled, which now we shall have the pleasure of searching out.

2448. Of the substances which compose the crust of the earth, by far the greater portion belongs to the diamagnetic class; and though ferruginous and other magnetic matters, being more energetic in their action, are consequently more striking in their phenomena, we should be hasty in assuming that therefore they overrule entirely the effect of the former bodies. As regards the ocean, lakes, rivers, and the atmosphere, they will exert their peculiar effect almost uninfluenced by any magnetic matter in them; and as respects the rocks and mountains, their diamagnetic influence is perhaps greater than might be anticipated. I mentioned that, by adjusting water and a salt of iron together, I obtained a solution inactive in air (2422.); that is, by a due association of the forces of a body from each class, water and a salt of iron, the magnetic force of the latter was entirely counteracted by the diamagnetic force of the former, and the mixture was neither attracted nor repelled. To produce this effect, it required that more than 48·6 grains of crystallized protosulphate of iron should be added to ten cubic inches of water (for these proportions gave a solution which still set equatorially), a quantity so large, that I was greatly astonished on observing the power of the water to overcome it. It is not therefore at all unlikely that many of the masses which form the crust of this our globe may have an excess of diamagnetic power and act accordingly.

2449. Though the general disposition of the magnetic curves which permeate and surround our globe resemble those of a very short magnet, and therefore give lines of force rapidly diverging in their general form, yet the magnitude of the system prevents us from observing any diminution of their power within small limits; so that probably any attempt on the surface of the earth to observe the tendency of matter to pass from stronger to weaker places of action would fail. Theoretically, however, and at first sight, I think a pound of bismuth or of water, estimated at the equator, where the magnetic needle does not dip, ought to weigh less when taken into latitudes where the dip is considerable; whilst a pound of iron, nickel, or cobalt, ought, under the same change of circumstances, to weigh more. If such should really prove to be the case, then a ball of iron and another of bismuth, attached to the ends of a delicate balance beam, should cause that beam to take different inclinations on different parts of the surface of the earth; and it does not seem quite impossible that an instrument to measure one of the conditions of terrestrial magnetic force might be constructed on such a principle.

2450. If one might speculate upon the effect of the whole system of curves upon very large masses, and these masses were in plates or rings, then they would, according to analogy with the magnetic field, place themselves equatorially. If Saturn were a magnet as the earth is, and his ring composed of diamagnetic substances, the tendency of the magnetic forces would be to place it in the position which it actually has.

2451. It is a curious sight to see a piece of wood, or of beef, or an apple, or a bottle of water repelled by a magnet, or taking the leaf of a tree and hanging it up between the poles, to observe it take an equatorial position. Whether any similar effects occur in nature among the myriads of forms which, upon all parts of its surface, are surrounded by air, and are subject to the action of lines of magnetic force, is a question which can only be answered by future observation.

2452. Of the interior of the earth we know nothing, but there are many reasons for believing that it is of a high temperature. On this supposition I have recently remarked, that at a certain distance from the surface downwards, magnetic substances must be entirely destitute, either of the power of retaining magnetism, or becoming magnetic by induction from currents in the crust or otherwise*. This is evidently an error; that the iron, &c. can retain no magnetic condition of itself, is very probably true, but that the magnetic metals and all their compounds retain a certain degree of power to become magnetic by induction, whatever their temperature, has now been proved (2344, &c.). The deep magnetic contents of the earth, therefore, though they probably do not constitute of themselves a central magnet, are just in the condition to act as a very soft iron core to the currents around them, or other inducing actions, and very likely are highly important in this respect. What the effect of the diamagnetic part may be under the influence of such inductive forces, we are not prepared to state; but as far as I have been able to observe, such bodies have not their power diminished by heat (2397.).

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* Philosophical Magazine, 1845, vol. xxvii. p. 3.

2453. If the sun have anything to do with the magnetism of the globe, then it is probable that part of its effect is due to the action of the light that comes to us from it; and in that expectation the air seems most strikingly placed round our sphere, investing it with a transparent diamagnetic, which therefore is permeable to his rays, and at the same time moving with great velocity across them. Such conditions seem to suggest the possibility of magnetism being there generated; but I shall do better to refrain from giving expression to these vague thoughts (though they will press in upon the mind), and first submitting them to rigid investigation by experiment, if they prove worthy, then present them hereafter to the Royal Society.

Royal Institution,
Dec. 22, 1845.

Feb. 2, 1846.—I add the following notes and references to these Researches:—

BRUGMANS first observed the repulsion of bismuth by a magnet in 1778. *Antonii Brugmans Magnetismus seu de affinitatibus magneticis observationes magneticæ.* Lugd. Batav. 1778, § 41.

M. LE BAILLIF on the Repulsion of a Magnet by Bismuth and Antimony, Bulletin Universel, 1827, vol. vii. p. 371; vol. viii. pp. 87. 91. 94.

SAIGEY on the Magnetism of certain natural combinations of Iron, and on the mutual repulsions of Bodies in general. Ibid. 1828, vol. ix. pp. 89. 167. 239.

SEEBECK on the Magnetic Polarity of different Metals, Alloys and Oxides. Ibid. 1828, vol. ix. p. 175.

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MDCCCXLVI.

ROYAL MEDALS.

HER MAJESTY QUEEN VICTORIA, in restoring the Foundation of the Royal Medals, has been graciously pleased to approve the following regulations for the award of them:

That the Royal Medals be given for such papers only as have been presented to the Royal Society, and inserted in their Transactions.

That the triennial Cycle of subjects be the same as that hitherto in operation: viz.

1. Astronomy; Physiology, including the Natural History of Organized Beings.
2. Physics; Geology or Mineralogy.
3. Mathematics; Chemistry.

That, in case no paper, coming within these stipulations, should be considered deserving of the Royal Medal, in any given year, the Council have the power of awarding such Medal to the author of any other paper on either of the several subjects forming the Cycle, that may have been presented to the Society and inserted in their Transactions; preference being given to the subjects of the year immediately preceding: the award being, in such case, subject to the approbation of Her Majesty.

The Council propose to give one of the Royal Medals in the year 1846 for the most important unpublished paper in Physics, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1843, and prior to the termination of the Session in June 1846.

The Council propose also to give one of the Royal Medals in the year 1846 for the most important unpublished paper in Geology or Mineralogy, communicated to the

Royal Society for insertion in their Transactions after the termination of the Session in June 1843, and prior to the termination of the Session in June 1846.

The Council propose to give one of the Royal Medals in the year 1847 for the most important unpublished paper in Mathematics, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1844, and prior to the termination of the Session in June 1847.

The Council propose also to give one of the Royal Medals in the year 1847 for the most important unpublished paper in Chemistry, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1844, and prior to the termination of the Session in June 1847.

The Council propose to give one of the Royal Medals in the year 1848 for the most important unpublished paper in Astronomy, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1845, and prior to the termination of the Session in June 1848.

The Council propose also to give one of the Royal Medals in the year 1848 for the most important unpublished paper in Physiology, including the Natural History of Organized Beings, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1845, and prior to the termination of the Session in June 1848.

The Council propose to give one of the Royal Medals in the year 1849 for the most important unpublished paper in Physics, communicated to the Royal Society after the termination of the Session in June 1845, and prior to the termination of the Session in June 1848, and printed in the Philosophical Transactions.

The Council propose also to give one of the Royal Medals in the year 1849 for the most important unpublished paper in Geology or Mineralogy, communicated to the Royal Society after the termination of the Session in June 1845, and prior to the termination of the Session in June 1848, and printed in the Philosophical Transactions.

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PHILOSOPHICAL TRANSACTIONS.

IV. *The Blood-corpuscle considered in its different Phases of Development in the Animal Series. Memoir* I.—*Vertebrata. By* T. Wharton Jones, *F.R.S., Lecturer on Anatomy, Physiology and Pathology, at the Charing-Cross Hospital, &c.*

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Part I.

THE mode in which I purpose to treat this part of my subject, is to trace the blood-corpuscle in its different phases of development in the vertebrate series, from the lower to the higher classes.

I commence therefore with the blood-corpuscle of the Skate, taken as an example of the lowest class.

Examination of the Blood-corpuscles of the Skate.

1. There are in the blood of the Skate two kinds of corpuscles, which at first view, under the microscope, especially attract the notice of the observer: the one kind is without colour, but appears dark in consequence of refracting the light strongly, is of a roundish form, and about $\frac{1}{1800}$th of an inch in diameter, or even larger; the other kind, which is more numerous, is of a red colour and oval form, and measures about $\frac{1}{1100}$th of an inch long, by $\frac{1}{1700}$th of an inch broad (figs. 1, 2 *a*, 3, and 7.).

2. *Structure of the first-mentioned kind of Corpuscle.*—The first-mentioned kind of corpuscle is composed of an agglomeration of granules surrounded by a cell-membrane. The granules are clear and strongly refract the light. They measure about $\frac{1}{20,000}$th of an inch in diameter, but it is to be remarked, that they may at one time appear separate, and at another time more or less fused together, as if they had been granules of quicksilver.

3. In consequence of the structure, so far as it has been described, of the corpuscle under consideration, I propose to designate it by the name of *granule blood-cell.*

4. On one side of this granule blood-cell, a clear spot may sometimes be seen, indicating the place of a nucleus (fig. 1.).

5. By the action of water, the cell-wall becomes distended so that it is enlarged in diameter; at the same time the aggregation of the granules becomes less close and their appearance of fusion less; sometimes I have seen the granules suddenly collapse and flatten under the action of water, as if they had been small vesicles bursting (fig. 2 *a*.).

6. By the action of acetic acid much diluted, the granulous mass is dissolved, but the cell-wall is left, and in its interior there is now distinctly seen a cellæform nucleus, about $\frac{1}{4300}$th of an inch in diameter (fig. 2 *b*.). I have watched individual cells during the action of the acid on them, and have seen one granule disappearing after another in the most beautiful and striking manner, until the nucleus came into view.

7. I have above spoken of the granule blood-cell as being of a roundish form: as the blood of the Skate subjected to examination was obtained from the blood-vessels of the viscera already removed from the animal, I cannot say what form the granule blood-cell would present in blood drawn from the animal during life and forthwith examined. But in some examples of the blood which I examined, and which was obtained at a time which could not have been long after the death of the animal, the granule-cells at first presented most remarkable changes of shape and other phenomena immediately to be described, which after a time ceased to be presented, the cells settling into a round form.

8. As the changes of shape and other phenomena to which I refer, resembled appearances presented by what we shall find to be the corresponding corpuscle in the blood of the Frog and of other animals, drawn during life, I am disposed to believe that they will also be found presented by the granule-cells of blood actually drawn from the living Skate.

9. My attention was first attracted to the phenomena by observing a granule-cell with the granules apparently escaping from it as if burst (fig. 3.). But the cell soon appearing again with all the granules collected together, I was led to watch, and soon perceived that the appearance of granules escaping, as if from a burst cell, was owing to this:—the transparent and colourless cell-wall bulged out on one side, leaving the granules still agglomerated and holding together, but this only for a short time; for soon single granules were seen to separate and burst out from the rest, and to enter the hitherto empty compartment produced by the bulging out of the cell-wall. The regular manner in which this sometimes took place was remarkable. I have actually seen the granules enter the compartment by one side and circulate along the bulging cell-wall to the other side, until the whole compartment became filled with granules. This having occurred the bulging began to subside, but was succeeded by a bulging of another part of the cell-wall, into which again a flow of granules took place; and so on all round the cell.

10. *Structure of the Red Oval Corpuscle.*—This is readily recognised to be an oval-shaped cell, with a nucleus round or oval, and with red-coloured contents. It thus resembles the well-known red corpuscle of the blood of the Frog, in structure as well

as in general appearance; the only difference being that its nucleus is cellæform, whereas that of the red corpuscle of the Frog is, as we shall find, rather solid-looking. The red oval corpuscle of the blood of the Skate under consideration, I propose to name *nucleated blood-cell*, in contradistinction to the granule-cell, which, though also nucleated, is not in general discovered to be so until after the solution of the granules by acetic acid, and which in consequence of its being filled with granules is otherwise well designated granule blood-cell*.

11. Besides the two kinds of cells which I have now described in the blood of the Skate, there are others which, on account of their paleness, do not at first attract so much attention, but which it is of the greatest importance particularly to notice.

12. One kind (fig. 4 *a.*) has the characters of the granule-cell, only the granular contents are very fine and do not so strongly refract the light, hence its paleness. This pale granule-cell I consider an advanced stage of the dark-looking granule-cell. This latter I will call the *coarsely granular stage*, the former the *finely granular stage* of granule-cell.

13. Another kind of the corpuscles referred to, has essentially the same structure as the red nucleated blood-cell above described, being a cell containing in its interior a cellæform nucleus (fig. 5 *a.*); the only difference is that both cell and nucleus are circular (the former about $\frac{1}{1800}$th of an inch in diameter, the latter about $\frac{1}{3000}$th), and that the cell is either destitute of colour or but slightly tinged red.

14. That this circular nucleated cell is an early stage of the oval red nucleated cell is shown by the circumstance, that besides it there are cells having the same structure but more or less oval-shaped, and still either altogether uncoloured, or slightly tinged red (fig. 6.), which evidently form a transition to the oval red nucleated blood-cell.

15. Two stages of the nucleated blood-cell may thus be recognised, an *uncoloured* and a *coloured stage.*

16. The description now given of the nucleated blood-cell of the Skate in the uncoloured stage, and a comparison of figures 5 *a.* and 2 *b.* will show that it resembles the granule blood-cell after its granules have been dissolved by the action of acetic acid; the only difference being that in the former the cellæform nucleus is larger and more developed.

17. This resemblance, and the circumstance that corpuscles occur in which the cellæform nucleus is large, but still surrounded by a few granules (fig. 4 *b.*; see also the corresponding corpuscle in the Lamprey, represented in fig. 2.), and which may be viewed as a transition from the granule to the nucleated cell, go to prove that the nucleated blood-cells are developed from the granule blood-cells—are, in fact, the granule blood-cells with the cellæform nucleus developed, at the expense of the granules which have disappeared.

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* The name "granule-cell" I have borrowed from Professor VOGEL of Gottingen, who first employed it to designate a form of cell which is developed in inflammatory exudations.

18. The conclusion to be drawn from what has now been said in regard to the relationship between the granule blood-cell and the nucleated blood-cell is, that they are to be viewed as two different phases of development of the same body, the granule-cell being the *first phase of development*, the nucleated cell the *second phase of development*. Each phase of development again comprehends two principal stages: the phase of granule-cell, *a coarsely and finely granular stage*; the phase of nucleated cell, *an uncoloured and a coloured stage.*

19. In the osseous fishes which I have examined for the purpose, the blood-corpuscle in its phases and stages of development is essentially the same as in the Skate. In the Lamprey also, which is a cartilaginous fish lower in the scale than the Skate, the blood-corpuscle in its phases and stages of development is the same, with the exception that the nucleated cell in its coloured stage is circular, as well as that in the uncoloured stage (figs. 4 *a*, 3.)[*].

20. It is worthy of remark, however, that there is a fish, the lowest of the lowest division, in which the blood is perfectly colourless, viz. *Branchiostoma lubricum*, COSTA, *Amphioxus lanceolatus*, YARRELL[†]. The corpuscles of the blood of this fish have not been examined, but there can be little doubt that some of them are the same as the granule blood-cells of the Skate or Lamprey, and others the same as the nucleated blood-cells in their uncoloured stage. If this be so, the blood of *Branchiostoma lubricum* would differ from that of other fishes, merely in the absence of nucleated cells in the coloured stage. It is quite possible, however, although the blood appears perfectly colourless, that nucleated cells in the very commencement of the coloured stage may exist.

21. From Fishes I now proceed to Reptiles, and as an example of a Reptile I take the Frog, in which to examine the blood-corpuscle.

Examination of the Blood-corpuscles of the Frog, and a comparison of them with those of the Skate.

22. In the blood of the Frog, as in that of the Skate, the following kinds of corpuscles are to be recognised:—granule-cells and nucleated cells; the former in coarsely and finely granular stages, the latter in uncoloured and coloured stages.

23. What are usually spoken of under the names of "lymph," or "colourless" corpuscles, are the granule-cell in both its stages, and the nucleated cell in its uncoloured stage. The relation of these corpuscles to the lymph will be considered in Part Second of this paper; here I view them as corpuscles existing in the blood, and therefore as blood-corpuscles; blood-corpuscles, moreover, differing from each other

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[*] Professor RUDOLPH WAGNER was the first to point out the circular form of the red blood-corpuscle of the Lamprey, but he does not appear to have noticed the existence of a nucleus.

[†] MÜLLER, Mikroskopische Untersuchungen über der Bau und die Lebenserscheinungen des *Branchiostoma lubricum*, COSTA, *Amphioxus lanceolatus*, YARRELL. Auszug aus dem Monatsbericht der konigl. Preuss. Akademie der Wissenschaften zu Berlin, Dec. 1844.

in their degree of development, and not to be confounded together under one specific name or epithet, whether "lymph" or "colourless."

24. *Granule Blood-cells.*—The corpuscle in the blood of the Frog, clearly identical with the granule blood-cell of the Skate in the coarsely granular stage, is roundish, and contains clear granules strongly refracting the light, like those of the same cell in the blood of the Skate, only not so large (fig. 1 *a.*). These granules are usually collected in greater number to one side. The cell itself I have seen, on carefully watching it in blood drawn from the living animal, exhibiting changes of shape with movements of the granules, such as have been above described in regard to the granule-cell of the Skate (par. 7 *et seq.*).

25. By the addition of water this granule blood-cell becomes somewhat distended, and if then *very much diluted* acetic acid, or rather to express myself more correctly, water very slightly acidulated with acetic acid, be added, the granules are dissolved and a cellæform nucleus about $\frac{1}{3500}$th of an inch in diameter comes into view (fig. 1 *b.*). If stronger acetic acid is added, instead of one such nucleus, the appearance of two or more smaller ones lying close together is apt to be presented.

26. The granule blood-cell in the finely granular stage of the Frog, when by the action of water it has become distended, presents itself of a regular circular form with a diameter usually about $\frac{1}{1200}$th or $\frac{1}{1300}$th of an inch, but sometimes greater, sometimes less (fig. 2 *b.*). It contains an indistinctly granular matter which does not refract the light much, and therefore it appears very pale.

27. Before being acted on by water, the cell under consideration usually presents itself of an irregular shape with processes shooting out from it (fig. 2 *a.*). After the blood is drawn, it rapidly undergoes the change to this shape, which, it is to be observed, is somewhat analogous to the change of shape which the coarsely granulous blood-cell presents.

28. When by the action of water the cell has been distended, a cellæform nucleus is sometimes already visible in the interior through the finely granular contents (fig. 2 *b.*), but by the action of acetic acid one is always brought distinctly into view. The diameter of this cellæform nucleus in the state of distention in which it is seen, may be put down at about $\frac{1}{2200}$th of an inch.

29. Instead of one cellæform nucleus of this size, an appearance of two, three, or even four smaller ones, may be brought out (fig. 2 *c.*), and this even more readily than in the case of the coarsely granulous cell (par. 25.). I am satisfied, however, that this is in both cases merely an appearance produced by the shrivelling together of the walls of the single cellæform nucleus in consequence of the action of the acetic acid.

30. It is proper to observe, that I have come to this conclusion only after having particularly tested the point by repeated, careful, prolonged and varied observations. Nor is the determination of the point of small moment, as on the appearance of a multiple nucleus which I have thus shown to be artificially produced, and on a similar, but I believe equally artificially produced appearance of a multiple nucleus in the

pus-corpuscle, a particular view has been founded as to the first formation of the nucleus, and indeed as to cell development generally. This subject I hope to consider on another occasion.

31. To return. I have observed that when the blood was treated with water first, so as to distend fully the cells in question, and then the acetic acid added in a very dilute state, never more than a single large cellæform nucleus came into view; whereas if the acid was added a little less diluted, and before the distending action of the water had been allowed to have its full effect on the cell, very generally an appearance of two or more small cellæform nuclei came into view. Though these nuclei have sometimes appeared as if detached from each other, they have been usually in contact, and I have been able to trace the contour of the original single cellæform nucleus from the one small body to the other.

32. By the action of water alone I have, indeed, sometimes seen, in those cells in which the nucleus is already visible through the finely granulous contents, an appearance as if the nucleus were subdivided into smaller, but very generally this has not been the case.

33. The distortion of shape, produced by external agencies, which I have now described as giving a false idea of the real structure of the cellæform nucleus of the granule-cell of the Frog, has its analogue in the now well-known distortion which the primitive tubules of nervous substance so readily undergo.

34. *Nucleated Blood-cells—Uncoloured stage.*—In the blood of the Frog, besides the granule-cells just described, there are seen uncoloured but distinct and well-defined corpuscles, round or oval, finely granulated, and refracting the light to a certain degree, and about $\frac{1}{3200}$th of an inch in diameter.

35. These corpuscles are apt to be confounded with the granule-cells, and appear to have been sometimes taken for free nuclei. They are nuclei but not free*, being surrounded by a cell-wall, which, without a good microscope and good light, is readily overlooked on account of its great paleness. This very pale cell, with distinct nucleus, which is the nucleated blood-cell in the uncoloured stage, may be circular (fig. 4.), or oval (fig. 5.), and of a size approaching that of the red corpuscle, or nucleated cell in the coloured stage.

36. Sometimes the pale cell-wall so closely embraces the nucleus as not to be distinguishable at all until distended and brought out by the addition of water, when it appears as represented in fig. 3.

37. This nucleated blood-cell in the uncoloured stage of the Frog is very similar to that of the Skate, the principal or indeed only difference being that its nucleus has become solid-looking and condensed, so that it has little of the cellæform appearance which the nucleus of the corresponding cell in the Skate presents.

38. *Nucleated Blood-cell—Coloured stage.*—This is the well-known red oval corpuscle of the blood of the Frog (fig. 6.). It is the counterpart of the red oval cor-

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* There may sometimes be seen free nuclei (par. 101.). *Note.*

puscle, or nucleated blood-cell in the coloured stage of the Skate, as above mentioned. The principal difference between the cells in question in the two animals, is in the character and appearance of the nucleus; whilst in the red cell of the Skate, the nucleus, though more or less oval, still retains its cellæform appearance; in that of the Frog it is still more solid-looking and condensed than it was in the nucleated cell in the uncoloured stage, and at last acquires the appearance as if consolidated by fusion into a small oval-shaped homogeneous mass.

39. The development of the red oval corpuscle or nucleated cell in the coloured stage from the nucleated cell in the uncoloured stage, can be readily understood to take place by the latter secreting into its interior colouring matter, becoming at the same time enlarged, and all this in the manner above explained in regard to the red nucleated cell of the Skate.

40. But as to the development of the nucleated cell in the uncoloured stage from the phase of granule-cell, this appears to take place in the following manner:—The cellæform nucleus of the granule-cell becomes developed into the solid-looking nucleus at the expense of the granules which disappear. As this takes place, the cell-wall contracts around the nucleus, becoming thicker and stronger, and by and by only becomes distended again by the accumulation of contents, as above described in the case of the Skate (par. 17.)*.

41. The blood-corpuscle of the Frog in its phases of development, thus resembles in all essential respects the blood-corpuscle of the Skate.

42. It would be supererogatory to institute a formal examination and comparison of the blood-corpuscle of any other oviparous vertebrate animal, but for the sake of what comparison may be desired, I have given figures of the blood-corpuscle of a bird in its different phases of development.

43. I now come to consider the blood-corpuscle of Man and the Mammifera in its different phases of development.

In the first place, it is to be observed that, as in the early embryonic state of the Mammifera, the red corpuscles of the blood are most of them very different from the red corpuscles of the blood in a more advanced stage of intra-uterine life as well as after birth, I will, in treating this subdivision of my subject, first examine the blood-corpuscles of the early embryo of a mammiferous animal, comparing them at the same time with those of the oviparous Vertebrata; and then I will examine the corpuscles of the fully-formed blood of Man and the Mammifera, comparing them with those of the early embryonic blood of the same class, and also with those of the blood of the oviparous Vertebrata.

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* The probability of such a mode of development of the red corpuscle of the blood of the Frog from the "lymph" or "colourless" corpuscle (granule-cell), has been already well-advocated by Professor H. Nasse and also by Dr. Baly in his translation of Müller's Physiology.

Examination of the Blood-corpuscles of an Embryo Ox, about $1\frac{1}{4}$ inch in length, and a comparison of them with those of Oviparous Vertebrate Animals.

44. The blood of this embryo presented the following kinds of corpuscles :—

1. Granule-cells in coarsely granular and finely granular stages.
2. Nucleated cells in uncoloured and coloured stages.
3. Small red corpuscles similar to those of the fully-formed blood of the animal.

45. *Granule-cells.*—Some of these contained pretty large and well-defined granules and refracted the light strongly,—coarsely granular stage (fig. 1.); others presented less defined granules, and refracting the light less, appeared very delicate and pale,—finely granular stage. Fig. 3 represents one of these cells with the cellæform nucleus already visible through the finely granular contents; this may be viewed as a transition to the phase of nucleated cell, whilst fig. 2 represents a granule-cell intermediate between the coarsely and finely granular stages.

46. The size of these granule-cells was from about $\frac{1}{1460}$th to about $\frac{1}{1825}$th of an inch in diameter.

47. *Nucleated Cells—Uncoloured stage.*—In these, as in the corresponding cells of the blood of the Frog, the nucleus, quite cellæform however, was very distinct, presenting a contrast with the scarcely visible cell-wall (fig. 4.). In some, as above described in the Frog (par. 36.), the cell-wall closely embraced the cellæform nucleus, so that this at first appeared free, until by the addition of water the extremely pale cell-wall was brought out. Often the distention of the cell-wall took place on one side only, presenting the appearance delineated in figure 5. In some again the cell-wall was not only distended but pretty distinct, and even slightly reddish (fig. 6.).

48. The size of the cellæform nucleus was from $\frac{1}{4860}$th to $\frac{1}{3650}$th of an inch in diameter, and the cell itself in those in which it was distended from about $\frac{1}{2430}$th to $\frac{1}{1460}$th of an inch in diameter.

49. *Nucleated Cells—Coloured stage.*—Most of these were circular (fig. 7 *a.*), but some were oval (fig. 8.). The circular measured about $\frac{1}{1930}$th of an inch in diameter. The oval measured about $\frac{1}{1460}$th in the long diameter and about $\frac{1}{2125}$th of an inch in the short diameter. The cellæform nucleus, when not at first evident, was brought distinctly into view by the addition of very dilute acetic acid, or even of water merely. It was circular, and measured from about $\frac{1}{4170}$th to about $\frac{1}{3650}$th of an inch in diameter (fig. 7 *b.*).

50. As to the *small red corpuscles similar to those of the fully-formed blood* (fig. 9.), they were rather larger than in the grown animal. They closely resembled the cellæform nuclei of the nucleated cells, only they were red, whilst the latter were uncoloured. There were some free corpuscles however uncoloured which resembled the cellæform nuclei of the nucleated cells, and also the small red corpuscles *minus* their colour.

51. Not having yet had an opportunity of examining the blood on its first appearance in the mammiferous embryo, I do not know if small red corpuscles already

exist then, but in embryos a little further advanced than that, the blood of which is at present under consideration, I found the number of small red corpuscles greater,—that of the nucleated red corpuscles less; and in fœtuses still farther advanced, the well-marked nucleated red corpuscles had altogether given place to the small red corpuscles.

52. Putting the small red corpuscles out of view, the blood of the early mammiferous embryo here examined resembles the blood of the oviparous Vertebrata in presenting, besides granule-cells, nucleated cells both in uncoloured and coloured stages.

53. In regard to the red nucleated cells it is to be remarked, that the circular ones were the most numerous, and as they are identical in appearance, size and structure, with the red corpuscles of the blood of the Lamprey, with the exception that their cellæform nuclei are larger, the blood of the mammiferous embryo might be compared to a mixture of the blood of the Lamprey, with a small quantity from a skate or frog to supply the few oval red nucleated cells, and a small quantity from a calf to supply the small red corpuscles.

54. I now proceed to examine the corpuscles of the fully-formed blood of Man and the Mammifera, and to compare them with those of the blood of the early mammiferous embryo and of oviparous vertebrate animals.

Examination of the Corpuscles of the fully-formed Blood of Man and the Mammifera, and a comparison of them with those of the Blood of the early Mammiferous Embryo and of Oviparous Vertebrate Animals.

55. In this examination and comparison, I will inquire,—first, if there be any corpuscles corresponding to granule-cells; secondly, if any corresponding to nucleated cells; and lastly, if the "red corpuscles" are found not to correspond to nucleated cells in the coloured stage, I will inquire into what they correspond to.

56. Here I omit, as I did above in the case of the blood-corpuscles of the Frog, the use of the terms "lymph" and "colourless" corpuscles as altogether destitute of definite meaning, purposing in the second part of this paper to consider, likewise in the case of Man and the Mammifera, what relationship exists between the corpuscles of their blood, usually confounded together under these names, and the corpuscles of their lymph.

57. *Granule Blood-cells.*—The corpuscles in the blood of Man and the Mammifera corresponding to the granule-cells of the blood of the animals above considered, are certain of those commonly spoken of under the name of "lymph" or "colourless" corpuscles—not all, as will be shown below, par. 66.

58. Both coarsely and finely granular stages of the granule-cell may be recognised. In human blood they in general become speedily collapsed after the blood is drawn, and some, especially those in the finely granular stage, may be seen on careful inspection shooting out processes (fig. 2 *u.*) like the same cells in the blood of the

Frog (par. 27.). In this state they look as if they had burst, but such is not the case in general.

59. By the addition of water, the collapsed granule-cells become distended and their appearance is thus distinctly brought out. Fig. 1 *a.* represents the human granule-cell in its coarsely granular stage thus distended; the contained granules, it will be observed, are minute, and on attentive observation they are seen to be in active molecular motion. Fig. 2 *b.* represents the finely granular stage of granule-cell of human blood, distended by water.

60. The granule-cell of human blood is sometimes seen to present, though not very strikingly, a clear spot indicating, as I think, the place of the nucleus, similar to that above represented in the case of the granule-cell of the Skate.

61. When distended by the action of water the human granule blood-cell is about $\frac{1}{2400}$th of an inch in diameter.

62. Fig. 3 *a.* represents the granule-cell, coarsely granular stage, and fig. 4 the granule-cell in its finely granular stage of the blood of the Horse. Figs. 5 *a.* and 6 represent the coarsely and finely granular stages of the granule-cell of the blood of the Elephant. It will be observed that the diameter of these cells is somewhat greater than that of the granule-cell of human blood, but the principal difference is the size of the contained granules in the coarsely granular stage. Whilst in the granule-cell, coarsely granular stage, of the Horse the granules may be estimated in round numbers at about $\frac{1}{15,000}$th of an inch in diameter, those in the same cell of the Elephant are about $\frac{1}{20,000}$th, and those in the human granule blood-cell about $\frac{1}{25,000}$th.

63. If, after the granule blood-cell has been distended by the action of water, very dilute acetic acid be added, the contained granules are dissolved, and a cellæform nucleus brought into view. Fig. 1 *b.* represents a human granule-cell so acted on; fig. 3 *b.* a granule blood-cell of the Horse similarly acted on; and fig. 5 *b.* a granule blood-cell of the Elephant in the process of being acted on by acetic acid. This last drawing was made before the granules were all dissolved, but when the cellæform nucleus was already distinctly in view. In the case of the cells here represented, as indeed in the case of many others, I watched the progress of the action of the acetic acid on the granules and the coming into view of the cellæform nucleus.

64. If, before the addition of the acid, the granule-cell has not been distended by the action of water, and if the acid has not been much diluted, instead of one cellæform nucleus of the size represented, and which in the human granule-cell may be about $\frac{1}{3650}$th of an inch in diameter, but larger in the Elephant and smaller in the Horse, an appearance of several smaller ones variously aggregated may be brought out. This, however, in opposition to what is generally believed, and in opposition to what I myself once believed, I can affirm most positively is merely an appearance artificially produced by the corrugating action of the acid on the walls of the single cellæform nucleus, altogether in the manner above shown to be the case with the cellæform nucleus in the corresponding cells of the blood of the Frog.

65. *Nucleated Blood-cells—Uncoloured stage.*—In human blood to which water has been added, besides the distended granule-cells, cells of the same size may be seen, not containing granules, but presenting most distinctly a single cellæform nucleus (fig. 7.). Such cells resemble the granule-cell deprived of its granules by the action of acetic acid. Moreover, it will be observed that they are essentially similar to the nucleated blood-cells in the uncoloured stage of the blood of the mammiferous embryo and of the oviparous vertebrate animals. In their mode of development from granule-cells, as indicated by the occurrence of cells in transition stages (fig. 10.) as well as in their structure, they are in fact clearly identical. I recognise them therefore as the corpuscles in human blood *in the phase of nucleated cell, uncoloured stage.*

66. In consequence of the collapsed state into which they fall immediately on the blood being drawn (fig. 8.), these uncoloured nucleated cells of human blood are scarcely to be distinguished from the collapsed granule-cells (fig. 2 *a.*) until after distention by water. They are usually confounded with them under the same name of "lymph" or "colourless" corpuscle.

67. In the blood of the mammiferous animals which I have yet examined in reference to the point under consideration, viz. the Horse, Elephant, Paco, Sheep, Goat and Rabbit, uncoloured nucleated cells likewise exist, those of the blood of one animal resembling those of the blood of another, and all resembling those of human blood in all essential particulars of structure. What difference there is consists in the size of the cell, but especially in the size of the cellæform nucleus, as may be seen by comparing the figures 9 and 11 of the nucleated blood-cells of the Elephant and Goat for example; the cellæform nucleus of the former being about $\frac{1}{3000}$th, that of the latter only about $\frac{1}{6000}$th of an inch in diameter.

68. *Nucleated Blood-cells—Coloured stage.*—In the blood of Man unacted on by reagents I have not yet observed such corpuscles, but in the blood of other mammifera which I have examined, especially in the blood of the Horse and Elephant, I have observed them. Fig. 13 represents one of several such corpuscles observed in the blood of the Horse which had been drawn from the animal for a day or two, but to which no water or other reagent had been added either before or during the examination. The transparent and colourless circumferential ring, the optical expression of the transparent and colourless cell-wall doubled on itself, formed a striking contrast with the red-coloured interior of the cell, as did also the uncoloured circumference of the cellæform nucleus. This nucleated cell differed from the nucleated cell in the uncoloured stage in not being collapsed. The one delineated was not plumply distended, but others were. Fig. 14 represents a coloured nucleated cell from the blood of the Elephant more fully distended.

69. Fig. 15 *a.* represents a nucleated cell slightly tinged red, which was observed in human blood, but only after the addition of water; fig. 15 *b.* represents a still more slightly tinged nucleated cell, observed likewise after the addition of water, in the blood of the Horse, and figs. 16 and 17 represent similar ones from the blood of the

Sheep and Paco. These may be looked on as transitions from the uncoloured to the coloured stage of nucleated cell, such as have been above referred to in the blood of the early mammiferous embryo and in that of the oviparous Vertebrata.

70. Having thus demonstrated, besides granule-cells both in coarsely and finely granular stages, nucleated cells, both in uncoloured and coloured stages, in the fully-formed blood of the Mammifera, as well as in their early embryonic blood, though in much smaller number and of a much less deep colour as regards the cells in the coloured stage*, I now come to inquire into the nature of the well-known "red corpuscles" of the fully-formed blood of the Mammifera.

71. *"Red Corpuscle" of the fully-formed blood of Man and the Mammifera.*—In consequence of similarity of colour, it has been generally taken for granted that this is the exact analogue of the "red corpuscle" or coloured nucleated blood-cell of the oviparous Vertebrata. Physiologists have accordingly supposed that it should contain a nucleus; but though unsuccessful in the attempt to demonstrate one, they have not altogether ceased to believe in the existence of an exact analogy between it and the "red corpuscle" or coloured nucleated blood-cell of the oviparous Vertebrata; they have rather had recourse to conjecture to account for the absence of a nucleus.

72. In reference to this point, the red nucleated cell of the blood of the early mammiferous embryo has been especially appealed to; it being considered by Mr. GULLIVER, and I think correctly, as the exact analogue of the "red corpuscle" or coloured nucleated blood-cell of the oviparous Vertebrata. But to take it for granted that the "red corpuscle" of the fully-formed blood of the Mammifera is the exact analogue of the red nucleated cell of their early embryonic blood, is not more warranted than to take it for granted that the "red corpuscle" of the fully-formed blood of the Mammifera is the exact analogue of the red nucleated blood-cell of the oviparous Vertebrata.

73. Under the impression however that the "red corpuscle" of the fully-formed blood of Man and the Mammifera is the exact analogue of the red nucleated cell of the blood of the early mammiferous embryo, Mr. GULLIVER endeavours to account for the absence of a nucleus in the former by supposing that it disappears at an early period of intra-uterine life. This apology for the absence of a nucleus in the "red corpuscle" of the fully-formed blood of Man and the Mammifera, would have had weight if the "red corpuscle" had been an object persistent throughout life like a limb or an eye, but as it is an object constantly disappearing and being regenerated, we should expect, if it were really a nucleated cell originally, to meet with it in a stage when it does contain a nucleus.

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* It is proper to mention that an appearance simulating that presented by the circumferential doubling of the cell-wall and by the slightly coloured interior of the nucleated cell, coloured stage, of fully-formed mammiferous blood, may be produced by the diffraction of the light around any corpuscle. As the diffracted shadows referred to however are always concentric with the corpuscle, error from this source may with certainty be avoided by the unpractised observer in all those cases at least, in which the cellæform nucleus is situated eccentrically within the cell.

74. Professors H. NASSE[*], SCHULTZ[†] and HENLE[‡], who appear to have observed the nucleated cell of the fully-formed mammiferous blood both in its uncoloured and coloured stages as above described, have supposed it to be the "red corpuscle" in such a stage. But its larger size (compare figs. 13 and 20, 14 and 23, 11 and 24) seems to forbid such a supposition. Supposing however that this objection could be waived, still it is nothing but unsupported conjecture to say that the nucleated cell and the "red corpuscle" are *exactly* the same body in different stages of development.

75. On the other hand, there is a chain of evidence which appears to me to point forcibly to a different view of the nature of the "red corpuscle" of the fully-formed blood of Man and the Mammifera, whilst by implication it as forcibly forbids the supposition that the nucleated cell and "red corpuscle" are exactly the same body—the latter the same as the former, only *minus* its nucleus, and with an increase of colour.

76. The view of the nature of the "red corpuscle" of the fully-formed blood of Man and the Mammifera to which I refer is this: the "red corpuscle" of the fully-formed blood of Man and the Mammifera is the cellæform nucleus of the nucleated cell set free by the bursting of this cell itself, and become filled and red by the secretion of globuline and colouring matter into its interior; and the chain of evidence which appears to me so forcibly to point to it is the following:—

77. 1st. *Correspondence in Size between the Cellæform Nucleus of the Nucleated Cell and the "Red Corpuscle."*—Whilst, as we have seen, there is a marked difference in size between the nucleated cell and the "red corpuscle" of the same blood, there is on the contrary a striking correspondence in size between the cellæform nucleus of the nucleated cell and the "red corpuscle." A glance at the figures will show this. In human blood, in which the "red corpuscle" is large, the cellæform nucleus of the nucleated cell is large. In the blood of the Horse, in which the "red corpuscle" is less, the cellæform nucleus of the nucleated cell is also less. Again, in Sheep's blood, in which the "red corpuscle" is still less, the cellæform nucleus of the nucleated cell is still less.

78. These facts, and the fact already pointed out by Mr. GULLIVER, that the nucleus of the red nucleated corpuscle of the blood of the early mammiferous embryo is about the same size as the "red corpuscles" in the same blood, which are similar to those of the fully-formed blood of the animal, were sufficient to draw my attention to the correspondence in size between the cellæform nucleus of the nucleated cell and the "red corpuscle," but not sufficient to satisfy me that it was more than a coincidence. I therefore became desirous of testing further the correspondence; and for this purpose it occurred to me that the blood of the Elephant (in which the "red corpuscles" are larger than those of any mammiferous animal, as Mr. GULLIVER has

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[*] Article "Lymphe," WAGNER's Handworterbuch. The blood referred to by NASSE was that of pregnant women especially.

[†] MÜLLER's Archiv, 1839, p. 252. The blood examined was that of the Elephant.

[‡] Algemeine Anatomie, p. 444, Pl. IV. fig. 1 E. *c*. The blood referred to appears to be human blood.

shown) and the blood of the Napu Musk Deer (in which, according to the same authority, the red corpuscles are smaller than those of any other mammiferous animal) would be well-adapted.

79. Accordingly I made application to the Council of the Zoological Society for leave to obtain a minute quantity of blood from the animals I have mentioned. With this request the Council of the Society readily complied*, so far as regards the Elephant, but could not as regards the Musk Deer, there being at present no specimen in their menagerie. As a substitute for the blood of the Musk Deer I have had recourse to that of the Goat, as distinguished for very small "red corpuscles."

80. The result of my examination of the blood of the Elephant is, that the cellæform nucleus of the nucleated cell is larger than that of any other animal the blood of which I have examined, and that it presents a remarkable and exact correspondence in size with the "red corpuscle" of the same animal. (See figs. 9 and 23.)

81. The result of my examination of the blood of the Goat is, that the cellæform nucleus of the nucleated cell is smaller than that of any other animal the blood of which I have examined. As to its correspondence in size with the red corpuscles, this does not at first view appear so complete as in the preceding instances; the large majority of "red corpuscles" being smaller than the cellæform nucleus of the nucleated cell. There are, however, some "red corpuscles"† which exactly correspond in size with the cellæform nucleus of the nucleated cell (see figs. 11 and 24), and these have all the characters of the early stage. (See below, par. 86.)

82. Notwithstanding this slight discrepancy in the blood of the Goat, which moreover is rather apparent than real, I believe that it will be admitted as a general proposition, that there is a close and constant correspondence in size between the cellæform nucleus of the nucleated cell and the "red corpuscle" of the same blood.

83. 2nd. *Correspondence in Form between the Cellæform Nucleus of the Nucleated Cell and the "Red Corpuscle."*—In the blood of the animals which I had hitherto examined, I had found the cellæform nucleus of the nucleated cell circular, and therefore so far corresponding in shape with the "red corpuscle;" but not considering this conclusive as to the existence of an essential relation in respect of form, it occurred to me that the point might be tested by a reference to the blood of the Camel tribe, in which the red corpuscles are of an oval shape.

84. Accordingly, availing myself of the liberal permission granted me by the Council of the Zoological Society, I procured a small quantity of the blood of the Paco, and subjected the cellæform nucleus of its nucleated cells to a comparison with its "red corpuscles." The result was that in the nucleated cells generally the cellæform

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* I most gladly seize the present opportunity to express my sense of the obligation thus conferred on me by the Council of the Zoological Society.

† The disproportion in size between the nucleated cell and the "red corpuscle" of the blood of the Goat is still greater than that between the nucleated cell and the "red corpuscle" of the blood of the other mammiferous animals which I have examined, and therefore still more strongly forbids the supposition that the nucleated cell and the "red corpuscle" are the same body.

nucleus was circular (fig. 12.). In a few nucleated cells indeed the cellæform nucleus was of a somewhat oval shape (fig. 17.), but this did not seem to be more than what I had occasionally observed in the blood of those Mammifera, in which the "red corpuscles" are circular.

85. My reference to the blood of the Paco thus appeared to decide against an essential correspondence in form between the cellæform nucleus of the nucleated cell and the "red corpuscle." A little further study of the blood of the Paco however soon cleared away this apparent difficulty, and showed me a state of things more corroborative of my view regarding the nature of the "red corpuscle," and in much closer correspondence with analogy perhaps than would have been that which I supposed possible. I discovered, in fact, corpuscles in different stages of transition, from the circular form similar to that of the cellæform nucleus within the nucleated cell, to the oval form of the perfect "red corpuscle;" and I also discovered that in these different stages of transition in respect of form there are different degrees of coloration (figs. 26, 27, 28, 29, 30.).

86. I had already observed progressive degrees of coloration in the circular "red corpuscles" of the Mammifera generally. Thus, in the blood of the Horse, for example, I had observed corpuscles (fig. 19.) similar on the one hand to the "red corpuscle" (fig. 20.) but uncoloured, and on the other to the cellæform nucleus of the nucleated cell (fig. 15.), and this in all respects. Such corpuscles I was disposed to regard as cellæform nuclei recently set free from the nucleated cells, but not yet reddened by the secretion of colouring matter into their interior. Again, I had observed corpuscles similar to those just mentioned but presenting a red tinge in the middle, the circumference untinged appearing like a transparent and colourless ring (fig. 21.); but the combination of progressive stages of coloration of the "red corpuscle" with its progressive changes of form in the blood of the Paco is peculiarly interesting.

87. The transition from the circular to the oval shape presented by the "red corpuscle" of the Paco, is analogous to that which we have seen presented by the red nucleated cell of the oviparous Vertebrata. It is also worthy of remark, that like the latter the oval red corpuscle of the Paco is reduced to a circular form by the action of water (fig. 31.). The progressive degrees of coloration are also analogous to what are presented by the nucleated cells of the blood of the oviparous Vertebrata. But it is curious to observe, that whilst among the Mammifera the attainment of the oval form by the "red corpuscle" is exceptional, among the oviparous Vertebrata the attainment of the oval form by the red nucleated cell is the rule.

88. But to return to the bearing of the facts I have now related on the question before us. They show that originally the "red corpuscles*" of the Paco are of a circular form like the "red corpuscles" of other mammifera, but that whilst the latter remain circular, the former gradually acquire an oval shape. From this it follows that the circular form of the cellæform nucleus of the nucleated cell of the blood of the Paco, so far from being an objection to the view of the nature of the "red corpuscle"

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* In their original circular form they are as yet uncoloured.

of the Mammifera which I am advocating, is just what should be according to it. In short, I consider the "red corpuscle" of the Paco, in its circular form and as yet uncoloured state, to be, like the similar corpuscles referred to in par. 86, cellæform nuclei but recently set free from the nucleated cell.

89. 3rd. *Correspondence in Structure between the Cellæform Nucleus of the Nucleated Cell and the "Red Corpuscle."*—The cellæform nucleus of the nucleated cell is a simple cell or vesicle without nucleus or nucleolus, and as such exactly resembles the "red corpuscle" *minus* its red coloured contents. Indeed, when by the action of water the "red corpuscle" is deprived of its red coloured contents without being rendered indistinct, the resemblance in respect of structure is very striking, as indicated by the lumen and transparent circumferential ring—the optical expression of the double contour of the wall of the collapsed cell or vesicle.

90. As already said, "red corpuscles" may occur uncoloured or with the lumen only red, the circumferential ring just referred to remaining transparent and colourless. This indicates that the colouring matter is contained in the interior of the cell or vesicle. In its perfect state however the "red corpuscle" appears red at the circumference also, owing, apparently, to its wall being impregnated with colouring matter.

91. The absence of anything like a nucleus in the "red corpuscle" of the fully-formed blood of the Mammifera is in correspondence with the absence of anything of the kind in the cellæform nucleus of the nucleated cell. The appearance of dots, as if of nucleoli, occasionally seen in the latter, I consider to be mere corrugations, similar to those which give rise to the mulberry appearance which the red corpuscle is so prone to assume.

92. Before admitting the correspondence in size, form and structure, between the cellæform nucleus of the nucleated cell and the "red corpuscle" of the blood of the Mammifera which I have now demonstrated, as evidence in favour of their identity, it will be proper to inquire if there be any points of difference between them sufficient to constitute evidence to the contrary effect.

93. *Points of Difference between the Cellæform Nucleus of the Nucleated Cell and the "Red Corpuscle."*—1st. The cellæform nucleus of the nucleated cell refracts the light more than the "red corpuscle." 2nd. The cellæform nucleus is not affected by water or acetic acid like the "red corpuscles"—the former being by the action of these reagents rendered more distinct, the latter rendered indistinct. These circumstances indicate a chemical difference between the cellæform nucleus and the "red corpuscle," and if a satisfactory explanation of them could not be offered they would constitute a powerful argument against my view. But I believe the following explanation will remove the difficulty.

94. *The objection against the identity of the Cellæform Nucleus and "Red Corpuscle" which might be founded on the different modes in which they refract light, and are affected by Chemical Reagents, explained away.*—The differences mentioned are striking enough between the cellæform nucleus and the "red corpuscle" in its perfect state; but if we take the "red corpuscle" in the stage when, as I have already described,

it is as yet uncoloured or presents colour only in its interior, then we find but little difference between it and the cellæform nucleus of the nucleated cell, either in the mode in which it refracts light, or in which it is affected by water or acetic acid. Even when fully red, the "red corpuscles" are not all equally affected by the action of water or acetic acid; some being always seen which resist to a greater or less degree the action of these reagents. Such corpuscles have been considered to be advanced formations, they appear to me on the contrary to be recent.

95. From this it appears that the "red corpuscle" in its advanced stage does not differ, in the respects under consideration, more from the cellæform nucleus of the nucleated cell than it does from what is undoubtedly itself in an early stage. The differences mentioned therefore argue nothing against the identity of the cellæform nucleus and the "red corpuscle."

96. There being thus no evidence to the contrary effect, the correspondence in size, form and structure, between the cellæform nucleus of the nucleated cell and the "red corpuscle" of the blood of the Mammifera, which I have now demonstrated, will I believe be admitted to constitute pretty forcible evidence as to their identity. Whether any additional evidence can be adduced will be seen in the sequel*, par. 106.

97. If the view of the origin and nature of the "red corpuscle" of the fully-formed blood of Man and the Mammifera which I have now given be correct, this "red corpuscle" must be considered as a third phase of development of the blood-corpuscle, and of which there occur uncoloured and coloured stages. This third phase I propose to call the phase of *free cellæform nucleus*†.

98. The different phases and stages of development of the blood-corpuscle in the Vertebrata, such as I have now traced them, may be summed up thus:—In all the vertebrate animals examined, oviparous, and mammiferous, we find blood-corpuscles in what I call the first phase of development, or phase of granule-cell, this presenting

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* The view of the nature of the "red corpuscle" of the fully-formed blood of Man and the Mammifera which I have now propounded, must not be confounded with Valentin's view that the blood-corpuscles are nuclei, seeing that he makes no distinction between the blood-corpuscles of the oviparous Vertebrata and those of the Mammifera in this respect. Considering them as analogous to each other, he views them equally as nuclei. The nuclei of the "red corpuscles" of the oviparous Vertebrata he considers to be nucleoli. According to my view, on the contrary, the "red corpuscles" of the blood of Man and the Mammifera are not the analogues of the "red corpuscles" of the blood of the oviparous Vertebrata, but strictly the analogues of their nuclei, as also of the nuclei of the nucleated "red corpuscles" of the blood of the early mammiferous embryo.

Messrs. Gulliver and Remak have made observations on the blood of the Horse, from which they have inferred that the "red corpuscles" are formed within the "colourless ones," and that they become free by solution of the latter. Gulliver however represents colourless corpuscles containing, some one, some two, and some even four "red corpuscles," and these nearly as large as the free "red corpuscles" of the animal. Remak, in like manner, speaks of one or more "red corpuscles" being formed within the colourless ones. Such appearances I have never observed.

† It appears almost unnecessary to remark, that this view of the nature of the "red corpuscle" of the fully-formed blood of Man and the Mammifera, completely sets aside the vexed question of a nucleus.

in a more or less marked manner two principal stages, a coarsely and a finely granular stage. In all the animals examined we likewise find blood-corpuscles in what I call the second phase of development, or phase of nucleated cell; this again presenting two principal stages, an uncoloured and a coloured. In *Branchiostoma lubricum* alone of all the oviparous Vertebrata, we have seen reason to conjecture (par. 20.) that the nucleated blood-cell occurs in the uncoloured stage only, or if a coloured stage exists, that the coloration is only in a very slight degree.

99. In regard to the nucleated blood-cell in the coloured stage, it is to be observed that it occurs in its highest degree of development and in great number only in the oviparous Vertebrata, in which it constitutes the "red corpuscle," and in the early mammiferous embryo. In the fully-formed blood of the Mammifera it occurs in a comparatively low degree of development, and in very small number.

100. It is in the Mammifera alone that we find the blood-corpuscle in what I call the third phase of development, or phase of free cellæform nucleus*. This exists in both uncoloured and coloured stages. In the former stage it is rare, in the latter it is the "red corpuscle" of the fully-formed blood of Man and the Mammifera. In the early mammiferous embryos which I have examined there have always been, in addition to the numerous "red corpuscles" similar to those of the oviparous Vertebrata, *i. e.* red nucleated blood-cells, some "red corpuscles" similar to those of the fully-formed mammiferous blood. Is there a period in the development of the mammiferous embryo when there exist in the blood no such "red corpuscles," viz. free cellæform nuclei in the coloured stage?

The summary now given will be found both tabularly and pictorially illustrated by the Plate.

PART II.

In this part of my subject, I purpose to examine the corpuscle of the lymph of vertebrate animals, and to compare it with the corpuscle of their blood.

The Corpuscle of the Lymph of the Skate and Mackerel.

101. The lymph of the Skate examined was obtained from the orbit in very small quantity, and could not be considered a good specimen. The corpuscles were besides a few granule-cells, nucleated cells in the uncoloured stage,—the cell-wall of many extremely pale,—and some nucleated cells in the earlier stage of coloration,—all identical with the corresponding corpuscles of the blood of the animal. (See figs. 1 to 6.)

102. The lymph of the Mackerel, taken as an example of an osseous fish, was likewise obtained from the orbit, and might be viewed as a good specimen. It contained granule-cells, nucleated cells in the uncoloured stage,—many with the cell-wall so pale as to be readily overlooked without attentive examination,—and nucleated cells

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* Free nuclei, which may be met with in the blood of oviparous Vertebrata, are to be looked upon as mere abortions of a third phase of the blood-corpuscle.

in the earlier part of the stage of coloration,—all identical with the corresponding corpuscles of the blood of the animal.

The Corpuscle of the Lymph of the Frog.

103. The lymph subjected to examination was obtained from one of the posterior lymph hearts. The corpuscles were,—1st. Corpuscles at once recognisable as identical with the granule-cells of the blood of the animal, and these in both coarsely and finely granular stages. There were also cells in transition from granule to nucleated cells. 2nd. Corpuscles which at first sight appeared to be free nuclei, but were discovered on closer examination to be inclosed within cells of a circular or oval form, and extremely pale. The identity of these cells with the nucleated cells, uncoloured stage, of the blood of the animal could not be overlooked. 3rd. A considerable number of red nucleated cells, the same as the "red corpuscles" of the blood. Many of these no doubt were derived from small blood-vessels which had been cut in opening the lymph heart, but some of them I am inclined to believe belonged to the contents of the lymph heart, those especially which appeared to be in an early stage of coloration. (See the figures of the blood of the Frog.)

The Corpuscle of the Lymph of the Common Fowl.

104. The lymph subjected to examination was obtained from a lymphatic gland. It contained,—1st. Corpuscles about $\frac{1}{3000}$th of an inch in diameter, less or more, identical with the granule-cells of the blood of the same animal; some being in coarsely and some in finely granular stages (figs. 1 to 2.). 2nd. Corpuscles in much greater number than the preceding, of the form of circular discs, with a depressed point in the centre about $\frac{1}{7000}$th of an inch in diameter, and though colourless very distinct. At first glance these corpuscles appeared to be free, but subjected to more careful examination, they were observed to be contained within a cell of a diameter of about $\frac{1}{3000}$th of an inch, the wall of which was extremely pale. Having once perceived it, however, there was no difficulty in recognising the whole as a nucleated cell identical with the nucleated cell of the blood of the animal, in its uncoloured stage (fig. 3.). There were some nucleated cells similar to those just noticed, but slightly tinged red in the interior; and besides such there were some oval nucleated cells, altogether similar to the oval red corpuscles of the blood of the animal, but coloured only, and that slightly in the interior, the circumferential doubling of the cell-wall appearing quite transparent and colourless.

The Corpuscle of the Lymph of Man and the Mammifera.

105. The description of the corpuscles of the lymph, here to be given, was drawn from the examination of those presented by the contents of the thoracic duct. Besides the contents of the thoracic duct of the human subject, I have also particularly examined the contents of the thoracic duct of the Rabbit, and found their corpuscles to be in all essential respects identical.

106. The corpuscles were,—1st. Granule-cells in both coarsely and finely granular stages, altogether similar to those of the blood (figs. 1, 2.). 2nd. Besides many cells in transition from granule to nucleated phase, nucleated cells in both uncoloured and coloured stages, quite the same as those of the blood (figs. 7 and 15 *a*.). The nucleated cells were fully distended independent of the addition of water, and were comparatively the most numerous of the corpuscles in the lymph; those in the coloured stage being more so than those in the uncoloured stage. Slight as the coloration of the coloured stage of the nucleated cell was generally, some few cells presented it perhaps in a more marked manner than is usually presented by the same cells as they occur in the fully-formed blood; in this respect approaching to the red nucleated cell of the blood of the early mammiferous embryo. Some even were of an oval shape. 3rd. A considerable number of free cellæform nuclei, both uncoloured and in different degrees of progressive coloration. These free cellæform nuclei were not much affected by the action of acetic acid or water. Lastly, there were seen here and there among the other corpuscles the empty shell of a nucleated cell in the coloured stage, with a free cellæform nucleus beside it as if just extruded by the bursting of the cell-wall. This is a circumstance which may be viewed as additional evidence, and this of a direct kind, in support of the view above given of the nature and origin of the "red corpuscle" of Man and the Mammifera.

107. From the account now given of the corpuscle of the lymph of vertebrate animals, it appears that it is identical with the corpuscle of their blood. In the oviparous Vertebrata, it occurs, like the corpuscle of their blood, in the two phases of granule and nucleated cell; whilst in Man and the Mammifera it occurs, like the corpuscle of their blood, in the three phases of granule-cell, nucleated cell and free cellæform nucleus.

108. The only difference that exists between the corpuscle in the lymph and the corpuscle in the blood, is, as regards the oviparous Vertebrata, the little degree of coloration which the coloured stage of nucleated cell as yet presents, and as regards the Mammifera, the small degree of coloration which the coloured stage of free cellæform nucleus has as yet attained.

109. The comparatively small total amount of corpuscles in the lymph is well-known. As regards the relative number in the different phases of the corpuscle, it is to be remarked that in the oviparous Vertebrata, the nucleated cells are, as in the blood, more numerous than the granule-cells. The nucleated cells are also more numerous than the granule-cells in the lymph of Man and the Mammifera, which is different from what obtains in their blood. Taking into account this relatively great number of nucleated cells, and the existence, though in less numbers, of free cellæform nuclei, we might compare the contents of the thoracic duct of a mammiferous animal, in respect both of the kinds of corpuscles and of their relative but not absolute numbers, with the blood of its early embryo state. The circumstances above-mentioned, that some of the nucleated cells of the contents of the thoracic duct present in the coloured

stage coloration in a pretty marked degree, and that some are of an oval shape, give additional exactness to the comparison[*].

[*] In the descriptions which have been given by authors of the corpuscles of the lymph much confusion exists. An exposure of the principal causes of this may perhaps prove useful and instructive.

1st. Observations made on the corpuscles of the lymph of oviparous vertebrate animals have been adopted as applicable to the corpuscles of the lymph of Man and the Mammifera, whereas it will have been seen from what has been above said, that the corpuscles of the lymph of the oviparous Vertebrata can no more be taken as an exemplification of the corpuscles of the lymph of Man and the Mammifera, than the blood-corpuscles of the former as an exemplification of those of the latter.

2nd. Hewson, it is known, gave the name of "central particles" to the nuclei of the red corpuscles of the blood of the oviparous Vertebrata. He at the same time supposed that he had seen similar particles in the interior of the red corpuscles of the blood of Man and the Mammifera.

Having observed in the juice of lymphatic glands, bodies which he supposed to be free, and which he recognised to be similar to the central particles of the red corpuscles of the blood, Hewson came to the conclusion that the central particles are at first free, and that they subsequently become surrounded with the red coloured cell-wall, which he called "vesicular portion[1]."

How Hewson should have come to this conclusion is explicable, as regards the juice of the lymphatic glands of Birds, on the following supposition. In the juice of the lymphatic glands of Birds, it has been above seen, that nucleated cells in the uncoloured stage exist in great numbers; but that whilst the nucleus is very distinct, the cell-wall is extremely pale. In consequence of this Hewson appears to have overlooked the cell-wall and distinguished the nucleus alone, but when the cell-wall had already become evident around the nucleus by having acquired colour, he naturally supposed that it was a new formation.

How Hewson should have come to the same conclusion as regards the lymph of Man and the Mammifera, however, is scarcely explicable on any supposition. For to say nothing of the circumstance that there is not a "central particle" in the red corpuscle of the blood of the Mammifera, Hewson's description of "central particles" in the juice of the lymphatic glands of the Mammifera cannot apply to the cellæform nuclei of the uncoloured nucleated cells, seeing that the cellæform nucleus of the uncoloured nucleated cell is nearly, if not as large, as the perfect red corpuscle itself, which he alleged to contain the "central particle." The difficulty is still the same, even supposing Hewson to refer to free cellæform nuclei in the uncoloured stage, and still greater supposing him to refer to granule-cells.

3rd. Since Hewson's time the cell-wall of the uncoloured nucleated cell in the lymph, especially of the oviparous Vertebrata, has continued to be generally overlooked, and the nucleus described as free. The nucleus moreover has been confounded with the granule-cell, which is what is commonly taken as the type of the "lymph-corpuscle." The same confusion prevails in regard to the lymph of Man and the Mammifera, with this additional complication, viz. that granule-cells have been confounded with free cellæform nuclei in the uncoloured stage.

Wagner participating in the error of confounding granule-cells with cellæform nuclei, but having seen and distinguished the cell-wall of nucleated cells, he has taken their cellæform nucleus for a granule-cell, which had acquired a cell-wall around it.

Of all the authors I am acquainted with, Henle alone has accurately distinguished the different forms of the corpuscle of the lymph of Man and the Mammifera, without however pointing out their relationship; but in his account of the corpuscles of the lymph of the Frog, he has fallen into inaccuracies similar to some of those which have been above pointed out.

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[1] He believed, it may be further remarked, though not immediately to our present purpose, that the central particles were first formed in the lymphatic glands, and, after being received into the blood from the trunk of the lymphatic vessels, were in the course of the circulation carried to the spleen, where they acquired the red vesicular portion; and so the "red corpuscle" was formed. He believed also that the addition of the vesicular portion might likewise take place in the lymphatic glands.

Explanation of the Plate.

PLATE I.

Lamprey.

Though it was not considered necessary to describe the blood-corpuscles of the Lamprey particularly, a few figures of them are given for the sake of comparison.

First Phase.—Granule-cell.

Fig. 1. Granule-cell somewhat distended by the action of water.

Second Phase.—Nucleated Cell.

Fig. 2. A blood-cell in a state of transition from the phase of granule-cell to that of nucleated cell.
Fig. 3. Nucleated cell, uncoloured stage.
Fig. 4 *a*. Nucleated cell, coloured stage.
Fig. 4 *b*. The same cell after the action of acetic acid, whereby the nucleus has been distinctly brought out.

Skate.

First Phase.—Granule-cell.

Fig. 1. A granule-cell in the coarsely granular stage, presenting a clear spot on one side indicating the place of the nucleus.
Fig. 2 *a*. Granule-cell distended by the action of water.
Fig. 2 *b*. The same cell after the action of acetic acid. The granules have been dissolved and a cellæform nucleus brought into view.
Fig. 3. Granule-cell in the act of changing its shape, with movements of its granules, as described, par. 30 *et seq*.
Fig. 4 *a*. Granule-cell in the finely granular stage after the action of water.

Second Phase.—Nucleated Cell.

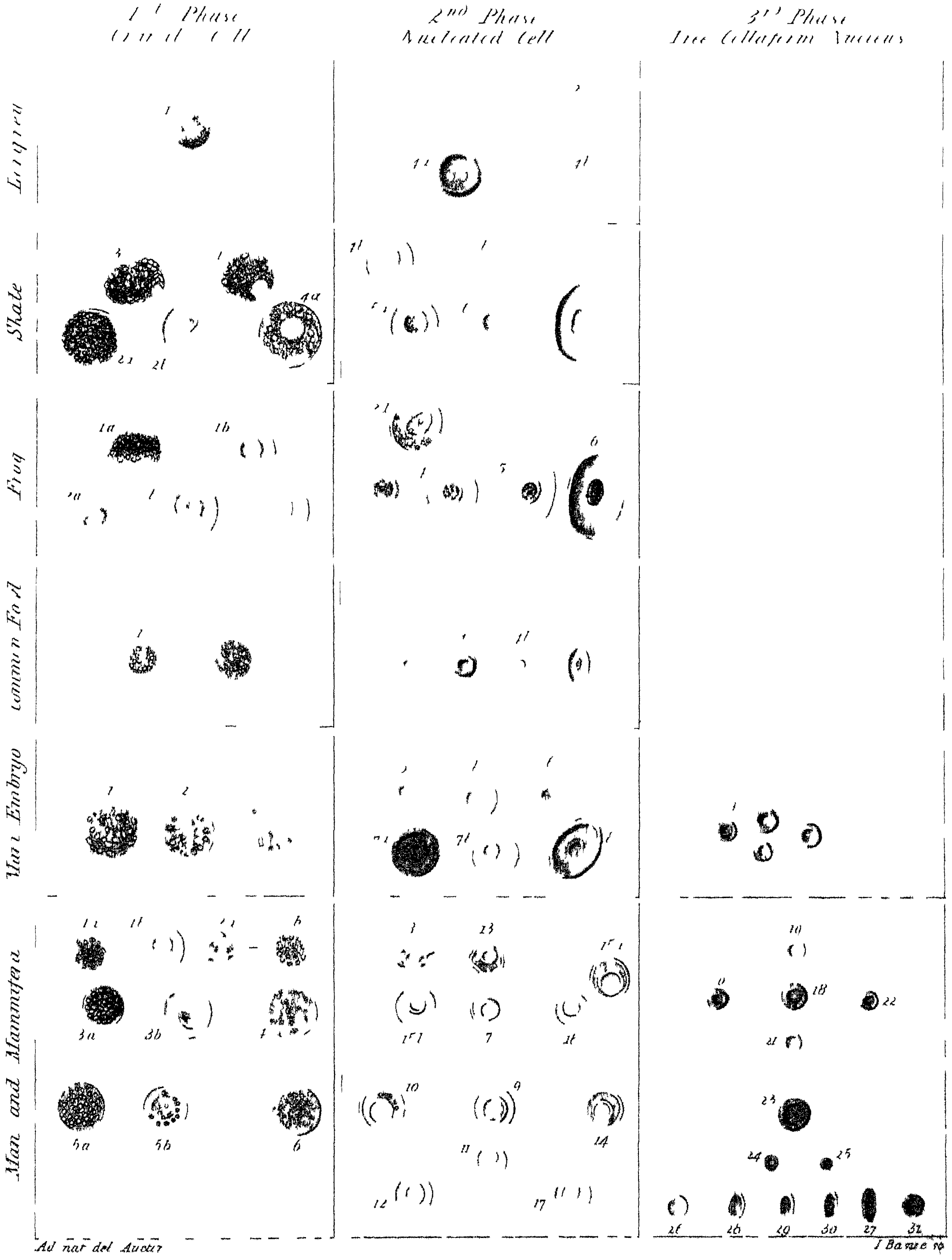
Fig. 4 *b*. A cell in transition from the phase of granule-cell to that of nucleated cell.
Fig. 5 *a*. Nucleated cell, uncoloured stage, circular.
Fig. 5 *b*. A similar cell collapsed.
Fig. 6. Nucleated cell in transition from the circular and uncoloured nucleated cell to the oval red nucleated cell, or nucleated cell in the second or coloured stage.
Fig. 7. The nucleated cell in the second or coloured stage.

Frog.

First Phase.—Granule-cell.

Fig. 1 *a*. Granule-cell in coarsely granular stage, and in the act of changing its

The Blood corpuscle in its different Phases of development in Vertebrate Animals



All the objects here represented are magnified 550 diameters
The microscope a compound one by Ross – the object glass ⅛th inch

Fig. 1 *b*. The same cell after the action of acetic acid. The granules have been dissolved and a cellæform nucleus exposed.

Fig. 2 *a*. Granule-cell in finely granular stage, after having collapsed and shot out processes.

Fig. 2 *b*. The same, distended by water.

Fig. 2 *c*. The same, after the action of acetic acid. If the acid has been very much diluted, and applied only after the distention of the cell by water, the appearance of the single large cellæform nucleus is produced; in the contrary case, the appearance of several small ones.

Second Phase.—Nucleated Cell.

Fig. 2 *d*. Cell in transition from granule to nucleated phase.

Fig. 3. Nucleated cell, uncoloured stage. The very pale cell-wall is seen on one side only of the very distinct nucleus.

Figs. 4 and 5. Nucleated cells, uncoloured stage, the one circular and the other oval.

Fig. 6. Nucleated cell, coloured stage, or the well-known oval "red corpuscle."

COMMON FOWL.

It has not been thought necessary particularly to describe the blood-corpuscles of the Bird. These few figures of the blood-corpuscle of the Common Fowl have been given merely for the sake of reference and comparison.

First Phase.—Granule-cell.

Fig. 1. Granule-cell, coarsely granular stage.

Fig. 2. Granule-cell, finely granular stage.

Second Phase.—Nucleated Cell.

Fig. 3. Nucleated cell, uncoloured stage.

Fig. 4 *a*. Nucleated cell, coloured stage, but still circular.

Fig. 4 *b*. The same cell, with the nucleus brought into view by the action of acetic acid.

Fig. 5. Nucleated cell, coloured stage, oval.

MAMMIFEROUS EMBRYO—Ox, 1¼ inch long.

First Phase.—Granule-cell.

Fig. 1. Granule-cell, coarsely granular stage.

Fig. 2. Granule-cell in transition from coarsely granular to

Fig. 3. Finely granular stage. This cell, in which the cellæform nucleus is already visible through the finely granular contents, may be viewed as a transition to the phase of nucleated cell.

Second Phase.—Nucleated Cell.

Fig. 4. Nucleated cell, uncoloured stage. The cell-wall, which is very pale, is seen all round the very distinct cellæform nucleus.

Fig. 5. Nucleated cell, uncoloured stage. The cell-wall, which has just been brought out by distention with water, is extremely pale, and is seen only on one side of the very distinct cellæform nucleus.

Fig. 6. A nucleated cell in transition to the coloured stage.

Fig. 7 *a*. Nucleated cell, coloured stage, circular.

Fig. 7 *b*. The same, after the action of acetic acid.

Fig. 8. Nucleated cell, coloured stage, oval.

Third Phase.—Free Cellæform Nucleus.

Fig. 9. Free cellæform nuclei, coloured stage, or "red corpuscles," similar to those of the fully-formed blood of the animal.

Man and the Mammifera.

First Phase.—Granule-cell.

Fig. 1 *a*. The granule-cell of human blood in its coarsely granular stage distended by water.

Fig. 1 *b*. The same, after being acted on by acetic acid. The granules have been dissolved and a single cellæform nucleus disclosed.

Fig. 2 *a*. The granule-cell of human blood in its finely granular stage in a state of collapse.

Fig. 2 *b*. The same, distended by water.

Fig. 3 *a*. The granule-cell, coarsely granular stage, of the blood of the Horse.

Fig. 3 *b*. The same, after being acted on by acetic acid.

Fig. 4. The granule-cell, finely granular stage, of the blood of the Horse.

Fig. 5 *a*. The granule-cell, coarsely granular stage, of the blood of the Elephant.

Fig. 5 *b*. The same, in process of being acted on by acetic acid.

Fig. 6. The granule-cell, finely granular stage, of the blood of the Elephant.

Second Phase.—Nucleated Cell.

Fig. 7. Nucleated cell of human blood, uncoloured stage, distended by water.

Fig. 8. The same, in a state of collapse.

Fig. 9. Nucleated cell of the blood of the Elephant in its uncoloured stage.

Fig. 10. The same, in a state of transition from the granule-cell.

Fig. 11. Nucleated cell, uncoloured stage, of the blood of the Goat.

Fig. 12. Nucleated cell, uncoloured stage, of the blood of the Paco.

Fig. 13. Nucleated cell, coloured stage, from the blood of the Horse.

Fig. 14. Nucleated cell, coloured stage, from the blood of the Elephant.

Fig. 15 *a.* Coloured nucleated cell from human blood.

Fig. 15 *b.* Nucleated cell, in transition from uncoloured to coloured stage, from the blood of the Horse.

Fig. 16. Nucleated cell, in transition from uncoloured to coloured stage, from the blood of the Sheep.

Fig. 17. Nucleated cell, in transition from uncoloured to coloured stage, from the blood of the Paco.

Third Phase.—Free Cellæform Nucleus.

Fig. 18. Free cellæform nucleus, coloured stage, of human blood.

Fig. 19. Free cellæform nucleus, uncoloured stage, of the blood of the Horse.

Fig. 20. Free cellæform nucleus, coloured stage, of the blood of the Horse.

Fig. 21. Free cellæform nucleus, in transition from uncoloured to coloured stage, of the blood of the Horse.

Fig. 22. Free cellæform nucleus, coloured stage, of the blood of the Sheep.

Fig. 23. Free cellæform nucleus, coloured stage, of the blood of the Elephant.

Figs. 24 and 25. Free cellæform nuclei, coloured stage, of the blood of the Goat.

Fig. 26. Free cellæform nucleus, uncoloured and circular stage, of the blood of the Paco.

Fig. 27. Free cellæform nucleus, coloured and oval stage, of the blood of the Paco.

Figs. 28, 29, 30. Free cellæform nuclei, in transition from uncoloured and circular stage to coloured and oval stage, of the blood of the Paco.

Fig. 31. Free cellæform nucleus, coloured stage, of the blood of the Paco rendered circular by the action of water.

V. *The Blood-corpuscle considered in its different Phases of Development in the Animal Series. Memoir* II.—*Invertebrata. By* T. WHARTON JONES, *F.R.S., Lecturer on Anatomy, Physiology and Pathology, at the Charing-Cross Hospital, &c.*

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THE invertebrate animals, of which I am here about to consider the blood-corpuscle in its different phases of development, are some of the more readily procurable examples of the divisions Annulosa and Mollusca. The order in which I purpose to proceed is from the higher to the lower classes of each division, an order the contrary of that adopted in the case of the Vertebrata.

ANNULOSA.

1. My examples of Annulosa are from the classes of Crustacea, Arachnida, Insecta, and Annelida.

Examination of the Blood-corpuscles of Crustacea.

2. As examples of Crustacea I have taken Crabs and Lobsters.

Blood-corpuscles of Crabs.

3. By snipping off the end of one of the legs of a Crab, the blood flows freely out from the stump, and is thus readily obtained*. A small quantity of the blood being received on a plate of glass direct from the animal, and forthwith examined under the microscope, it is seen to contain a very considerable number of corpuscles.

4. *Kinds of Corpuscles.*—Both granule-cells and nucleated cells,—the latter the more numerous,—may be distinctly recognised.

5. *Shape of the Cells.*—If very great expedition has been employed in receiving the blood as it flows from the animal on the plate of glass, spreading it out and transferring it to the microscope for examination, the granule-cells may be seen to be of an elongated oval shape, the nucleated cells spindle-shaped (figs. 1 and 6.). These shapes however are speedily changed.

6. As regards the granule-cell, it tends to become circular (figs. 2 and 3.), but it

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* The blood as it flows from the animal appears of a pale reddish gray or neutral tint; when collected in a watch-glass, it separates into a spongy-looking mass and a serous fluid. This spongy-looking mass, which is of a slight pink colour, consists principally of the corpuscles aggregated, there being little spontaneously coagulable material in the plasma to form a true clot. The serous fluid, which is bluish by reflected light, and reddish by transmitted light, is coagulated by heat, and also by *acetic acid.*

is also soon observed that its cell-wall bulges out here and there into round processes which again subside, whilst another part of the cell-wall bulges out in the same way. This change of shape, it will be perceived, is similar to that which I particularly described in the case of the granule-cell of the blood of the Skate, only it is to be remarked, that it is not accompanied by such a well-marked movement of the contained granules. Besides bulging out into round processes, the cell-wall may be seen to shoot out into cilia-like processes also (fig. 4.).

7. As regards the nucleated cell, it also first tends to become circular, and then shoots out its wall into processes which are usually more cilia-like than in the case of the granule-cell; and being in all directions like radii, the cell comes to present a stellate appearance (figs. 7, 8, 9.). Sometimes a cell is seen to shoot out into processes in two principal directions only, these processes again shooting out into smaller, so that the cell acquires a caudate form. Between this shape and the former there is every intermediate degree.

8. *Size of the Cells.*—When first examined, and before their shape has become changed, the granule-cells are about $\frac{1}{1800}$th of an inch long by about $\frac{1}{3000}$th of an inch broad. The nucleated cell is rather less in size, or perhaps with about the same length; it is not quite so broad.

9. *Structure of the Granule-cell.*—There are both coarsely and finely granular stages of the granule-cell. The granules appear more or less fused together, and are of a slightly greenish yellow colour when the microscopical examination is made by day-light.

10. By the addition of water the cell-wall is brought out very distinctly. Imbibing the water, the cell becomes distended and acquires a circular shape, and this as well after it has shot out into processes as when the water is added to the blood just drawn, and before the cell has lost its original shape. Fig. 5 *a.* represents a granule-cell as acted on by water.

11. In consequence of acetic acid producing a copious white curdy precipitate on its addition to the blood, some difficulty was at first experienced in studying the action of that acid on the blood-cells, but by previously diluting the blood with much water, the precipitate was not considerable enough to prevent the observation of the action of the acetic acid on the blood-cells.

12. When the acid comes into contact with the granule-cell, the granulous mass is dissolved, the granules disappearing one after the other, as already described in regard to the granule-cell of the Skate, &c. After the solution of the granulous mass, there is discovered in the interior of the cell, a cellæform nucleus about $\frac{1}{7000}$th of an inch in diameter (fig. 5 *b.*).

13. A clear spot which may be observed on the side of the granule-cell in blood just drawn (figs. 1, 2, 3.), and which is similar to that presented by the granule-cell of the blood of the Skate, appears to be, as in the Skate, produced by the nucleus peering through a pore in the granulous mass.

14. *Structure of the Nucleated Cell.*—By the action of water, the nucleated cell is distended and rendered circular even after it has shot out processes and acquired a stellate appearance. During this action of the water, the processes of the cell-wall may be observed to become broader and shorter, and to run into each other until the outline of the whole cell is circular, as in fig. 10. Within the cell thus distended, the cellæform nucleus is seen circular, and about $\frac{1}{3500}$th of an inch in diameter.

15. By the addition of dilute acetic acid, the nucleated cell is not further materially affected.

16. Although a decided coloured stage of nucleated cell does not exist in the blood of the Crab, it is proper to observe that many of the nucleated cells transmit the light through their interior of a very slight red tint. The circumferential doubling of the cell-wall transmitting the light quite colourless, forms with the interior a well-marked contrast. Though the red tint is more marked by lamp-light, it is sufficiently distinct by day-light. It has been above mentioned, that when the corpuscles collected in a mass are viewed by reflected light, they also appear slightly pink.

17. Besides granule-cells and nucleated cells such as have now been described, cells occur in which the cellæform nucleus is already visible, but still surrounded by some granulous matter (fig. 11.). These may be viewed as cells in a state of transition from granule to nucleated cell.

18. It may thus be concluded, that in Crabs the blood-corpuscle presents itself in two different phases of development, as in the oviparous Vertebrata, viz. the phases of granule-cell and of nucleated cell, the granule-cell being the first phase of development, the nucleated cell the second phase.

19. Floating about amongst the blood-corpuscles, there are seen a few elementary granules, the larger of which, from $\frac{1}{6000}$th to $\frac{1}{12,000}$th of an inch in diameter, have the form of biconcave circular discs.

Blood-corpuscles of the Lobster.

20. The description which has now been given of the blood-corpuscles of the Crab, is in all respects applicable to those of the Lobster*.

Examination of the Blood-corpuscles of Arachnida.

21. It was the *common Spider* the blood of which I examined; and the mode in

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* The changes of form which the blood-corpuscles of the Lobster, like those of the Crab, undergo after the blood is drawn, were described and delineated by HEWSON as accurately as his microscope appears to have enabled him to observe them. HEWSON also mentions what I have found to be the case, that the blood of the Lobster, "after being some time exposed to the air, jellies, but less firmly than the blood of more perfect animals." In this respect the blood of the Lobster differs from the blood of the Crabs which I examined; the blood of the latter, as I have above stated, not containing a sufficient quantity of spontaneously coagulable material to form a perfect clot. It may be proper to remark that it was in the beginning of winter when I examined the Crab's blood, and in the beginning of spring when I examined that of the Lobster.

which I obtained the blood was the same as that already stated in regard to the Crab and Lobster, viz. by snipping off one of the legs and receiving on a plate of glass the minute drop of blood which oozed out.

22. The blood-corpuscles of the Spider are almost identical with those of the Crab and Lobster. There are both granule-cells and nucleated cells,—the latter the more numerous,—which when examined immediately on the blood being drawn from the animal, present, the former an oval, the latter an elliptical shape (figs. 1, 2 and 7.). These shapes, however, are in general soon lost. The cells become roundish, their cell-wall at the same time shooting out into processes. This shooting-out of the cell-wall into processes is more especially presented by the granule-cells (fig. 3.), for in the case of the nucleated cell, it might be said that the cell-wall in general rather becomes shrivelled and collapsed than shoots into cilia-like processes (fig. 8.).

23. The size of the corpuscles is much the same as in the Crab.

24. There are both coarsely and finely granular stages of the granule-cell (figs. 1 and 2.), and also cells in transition from the granule to the nucleated phase.

25. By the action of water, the cell-wall of both granule and nucleated cell is distended and brought out in the same way as in the case of the blood-cells of the Crab (figs. 4, 5 and 9.), and by the action of acetic acid the granules of the granule-cells are broken up and dissolved, leaving the nucleus exposed (fig. 6.).

26. In regard to a coloured stage of nucleated cell, what was above said in the case of the Crab (par. 16.), is applicable here.

27. As in the blood of the Crab also, a few elementary granules are seen floating about.

Examination of the Blood-corpuscles of Insecta.

28. In entering on the examination of the blood-corpuscles of insects, the advantage of having first examined those of Crabs and Spiders is strongly felt; for the blood of these animals being readily and certainly obtainable free from admixture with foreign particles, which might be confounded with blood-corpuscles, the characters of their blood-corpuscles will serve as a guide by which to recognise their analogues in the blood of insects and other invertebrate animals, the conformation and structure of the bodies of which are such that we cannot be sure that the blood obtained from them is quite free from foreign admixture.

29. As examples of perfect insects I have taken Beetles, and as examples of chrysalises I have taken those of the Cabbage Butterfly[*].

Blood-corpuscles of Beetles.

30. The matter examined as the blood of these insects was the clear greenish

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[*] I have also examined the blood-corpuscles of the Caterpillar, and found them in essential particulars the same. Having, however, as yet obtained but one specimen of a caterpillar of the Cabbage Butterfly, I am not able to give here a description and delineation of the blood-corpuscles. This, however, I shall be able to do on another occasion.

yellow fluid which exuded when a small wound was made in the body of the animal.

31. In this fluid there were recognised, amidst a number of other corpuscles the nature of which will be inquired into below, corpuscles corresponding in essential characters to the granule and nucleated blood-cells of the Crab and Spider.

32. *Granule Blood-cells.*—These were, when seen immediately on the blood being drawn, of an elliptical or oval shape (fig. 1.), but they soon became round. In this state some might be seen with the cell-wall shot out into small cilia-like processes (fig. 2.). By the action of water, the cell becoming distended, these processes disappeared (fig. 3.).

33. The size of the cells under consideration was on an average $\frac{1}{2000}$th of an inch long by $\frac{1}{4000}$th broad.

34. The cells were most of them pale-looking, but some presented coarser and more refracting granules than others.

35. *Nucleated Blood-cells.*—These were much more numerous than the granule blood-cells. When the blood was first examined on being drawn, the cellæform nucleus, of an oval shape, measuring $\frac{1}{3650}$th by about $\frac{1}{7000}$th of an inch, and reddish in its interior, was the part most distinctly seen. The cell-wall, which might sometimes be seen of an elliptical shape (fig. 4.), was in general already found shrivelled and collapsed around the cellæform nucleus, or shot out into processes (fig. 5.). It was extremely pale and not always very readily distinguished. On the addition of water, however, it became distended and was then pretty distinctly seen (fig. 6.). In this state it was circular and measured about $\frac{1}{2000}$th of an inch in diameter.

36. In regard to the other kinds of corpuscles contained in the blood of the Beetle, they were, 1st,—a few corpuscles resembling the cellæform nuclei of the nucleated cells, but around which no cell-wall could be detected; 2nd, some oil-globules; 3rd, a great number of elementary granules in size from about $\frac{1}{7000}$th of an inch in diameter downwards, the larger being biconcave, circular, and of a yellowish or reddish colour.

Blood-corpuscles of the Chrysalis of the Cabbage Butterfly.

37. The matter examined as blood was the clear green fluid which flowed out on slight pressure, when a small point of the anterior end of the chrysalis was snipped off.

38. In this fluid there were both granule-cells and nucleated cells (figs. 7, 8, 9, 10, 11, 12.), together with elementary granules.

Examination of the Blood-corpuscles of Annelida.

39. As examples of Annelida, I have taken the common Earth-worm and the medicinal Leech.

Blood-corpuscles of the Earth-worm.

40. The blood was most readily obtained for examination from the abdominal vessel, but in abstracting it, care was required to guard against its becoming mixed with the secretion poured out from the skin in great abundance when the animal was wounded.

41. The corpuscles of the blood of the Earth-worm are remarkable for their great size, being on an average $\frac{1}{1100}$th or $\frac{1}{1200}$th of an inch in diameter. There are both granule and nucleated cells.

42. *Granule Blood-cells.*—Of these there are both coarsely and finely granular stages. I have not observed the cell-wall of the granule-cell in the coarsely granular stage to shoot out into more than perhaps a single bud-like process (fig. 1.), but in the finely granular stage, the cell-wall shoots out into so many cilia-like processes, that the cell soon after the blood is drawn presents a stellate form (fig. 2.), the granulous mass about $\frac{1}{1800}$th of an inch in diameter occupying the centre.

43. By the action of water the granule-cells become uniformly distended (figs. 3 and 4.), the stellate form into which the cell in the finely granular stage had fallen disappearing. In this state of distention the cells measure $\frac{1}{1100}$th or $\frac{1}{1200}$th of an inch in diameter, but their granulous contents do not fill their whole interior.

44. Acetic acid causes the granules of the cell in the coarsely granular stage to break up, but does not dissolve their substance. The granulous contents of the cell in the finely granular stage it renders more transparent.

45. *Nucleated Blood-cells.*—Instead of perfect nucleated cells, the cells about to be described under this head might, perhaps, rather be said to be cells in transition from the granule-cell phase, inasmuch as the nucleus, though quite evident, is still surrounded by granular matter.

46. The cells under consideration have always been collapsed when first seen, though the blood was examined as quickly as possible after being drawn; but I have observed them in the act of shooting out their cell-wall into processes (fig. 5.), like the granule-cell in the finely granular stage.

47. By the action of water, the processes are made to disappear by the cell becoming uniformly distended. In this state the cell measures about $\frac{1}{1100}$th of an inch in diameter, and in its interior is seen the cellæform nucleus about $\frac{1}{3600}$th of an inch in diameter, with a finely granulous mass surrounding it (fig. 6.). This granulous mass is not dissolved entirely by acetic acid, but it is rendered more transparent.

48. The red colour of the blood of the Earth-worm is, as is known, seated in the plasma, but it is to be remarked that some of the nucleated cells appear very slightly tinged, as also the nuclei, in their interior.

49. Besides the nucleated cells now described, corpuscles are met with altogether like their nucleus and its surrounding granulous mass, both in form and size.

50. Lastly, there are a few corpuscles like perfectly free nuclei, and a considerable number of elementary granules, the larger, of the form of biconcave circular discs.

Blood-corpuscles of the Medicinal Leech.

51. The blood examined was obtained by making incisions on the back or side of the animal after having carefully wiped the surface of the skin. In making these incisions care was taken not to cut into the stomach, or its cæcal appendages, in order to obviate the possibility of foreign blood which might have been taken in as food, becoming mixed with the real blood of the animal itself.

52. In the first place it is worthy of remark, that whilst the corpuscles of the blood of the Earth-worm are the largest which I have yet found in any invertebrate animal, the corpuscles of the blood of the Leech are the smallest.

53. When the blood of the Leech is examined under the microscope as soon after its abstraction from the animal as possible, numerous corpuscles are seen having the appearance of very pale, shining, colourless, fusiform filaments, about $\frac{1}{2000}$th of an inch in length, and about $\frac{1}{7000}$th of an inch in breadth, less or more (fig. 9.), suspended in the red-coloured plasma. Very soon, however, the corpuscles are seen gradually to become shorter and somewhat broader, until at last they acquire an irregular circular form (fig. 10.).

54. In this state the majority of the corpuscles appear to be composed of a nucleus surrounded by a collapsed and shrivelled cell-wall. And that this is so, is reduced to a certainty by the addition of water, which causes the cell to become distended and to acquire a circular form, whilst the outline of the cellæform nucleus appears more distinctly defined (figs. 11 and 12.).

55. Thus distended, the cell is from $\frac{1}{3000}$th to $\frac{1}{3600}$th of an inch in diameter, and the nucleus $\frac{1}{7000}$th, or more.

56. Many of the cells transmit the light slightly tinged red, as if there was some colouring matter lining their interior (fig. 12.).

57. The corpuscles of the blood of the Leech now described, it will have been observed, are *nucleated cells.*

58. *Granule-cells.*—Corpuscles in the blood of the Leech referrible to this head are few in number. Examples of them are delineated in figs. 7 and 8*.

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* I subjoin here a description of the corpuscles of the blood vomited by leeches which have never been used. This blood I found to be composed of a coloured plasma, and numerous corpuscles having a considerable resemblance to those of the blood of the animal itself after having lost their original fusiform shape, and become somewhat distended by water. On the whole, however, the corpuscles of the blood in question were somewhat larger, and appeared perhaps better defined than those of the Leech itself, especially the granule-cells, which were also more numerous, though still not so numerous as the nucleated cells.

Of the granule-cell there were both coarsely and finely granular stages (figs. 13 and 14.). There were cells in transition from the granule to the nucleated phase (fig. 15.). The nucleated cells (figs. 16, 17 and 18.) were most of them circular, but some were oval. Most appeared tinged red in their interior, those which did not had their cell-wall so very pale that it was apt to be overlooked.

The blood contained in the stomach of leeches which have not been used, and of which I have now briefly described the corpuscles, from what animal is it derived? The resemblance of the blood to that of the animal itself suggests the probability that medicinal leeches suck the blood of some other kind of leech. That they suck each other's blood has been positively denied by Dr. Rawlins Johnson.

MOLLUSCA.

59. My examples of Mollusca are confined to the classes of Gasteropoda and Acephala,—from the former I have taken the Whelk (*Buccinum magnum*),—from the latter the Mussel (*Mytilus edulis*), in which to examine the blood-corpuscles.

Blood-corpuscles of the Whelk.

60. The shell having been broken to pieces from around the animal, the blood was readily obtained from the great vessels of the heart, or from the heart itself; but notwithstanding every care in abstracting it, the blood was not always quite free from admixture with foreign particles, such as ciliated epithelium-cells and the like.

61. *Kinds of Corpuscles.*—There were granule-cells and nucleated cells essentially similar to those of the blood of Annulosa.

62. *Granule-cells.*—By the time the blood could be examined, the granule-cells had, for the most part, become agglomerated together in groups, and their cell-wall was seen already shot out into processes (fig. 1.).

63. Both coarsely and finely granular stages of the granule-cell were to be recognised.

64. The size of the granule-cell was on an average from $\frac{1}{3000}$th to $\frac{1}{2000}$th of an inch.

65. By the action of water the cell became uniformly distended (fig. 2.), to the size of about as much as $\frac{1}{1500}$th of an inch in diameter and then burst, the cell-wall disappearing and leaving the granulous contents in a mass with the nucleus visible in the centre (fig. 3.).

66. *Nucleated cells.*—Some of these were seen with the cell-wall shot out into processes (fig. 4.); some not (figs. 5, 6 and 7.).

67. Those cells of which the cell-wall did not shoot out into processes, were for the most part circular (figs. 5 and 6.); but some also occurred which appeared to be elliptical (fig. 7.), though these might have been circular cells seen somewhat raised up on edge. The cells under consideration often presented a finely granulous matter in their interior, and some were slightly tinged of a red colour. Their size was about $\frac{1}{2500}$th of an inch in diameter.

68. Those cells of which the cell-wall shot out into processes, when uniformly distended by water, were larger, measuring about $\frac{1}{1650}$th of an inch in diameter fig. 4 *a.*).

69. The nucleus, oval or circular, and reddish in the interior, measured on an average from $\frac{1}{4800}$th to $\frac{1}{3650}$th of an inch, these being the means when the nucleus was oval.

70. Besides the corpuscles now described, there were a few like free nuclei, and a great quantity of elementary granules of different sizes, the larger biconcave and circular

Blood-corpuscles of the Mussel.

71. The way in which I obtained the blood of the Mussel was this:—I first removed one valve of the shell with as little injury to the animal as possible, and allowed the contained fluid to drain away; I then opened the great vessel proceeding from the heart to the anterior part of the body, and introducing the microscopical forceps towards the heart, took up enough of the blood for one examination. Notwithstanding this careful procedure, the blood was often mixed with foreign corpuscles, such as the spermatozoa and ova of the animal.

72. *Kinds of Blood-corpuscles.*—There were in the first place *granule-cells*, which, like those of the blood of the Whelk, were found by the time the blood could be examined, already for the most part agglomerated together, and presenting their cell-wall shot out into processes (figs. 1 and 2.). The granulous contents appeared as if fused, forming a clear, more or less strongly refracting mass.

73. By the action of water this mass was broken up into separate granules, and at the same time the cell was observed to become gradually distended and rendered uniformly circular by the undoing of the processes into which its wall had shot. This undoing of the processes I have often, as in the case of the blood-cells of other animals, watched step by step.

74. When the cell had become fully distended, the granulous contents were usually next seen to escape by the bursting of the cell-wall, and to accumulate around its outside, whilst a nucleus from about $\frac{1}{7000}$th to $\frac{1}{4000}$th of an inch in diameter, and now for the first time seen, remained in the interior; the cell-wall, different from that of the granule-cell of the Whelk, continuing quite visible and otherwise entire (fig. 3.).

75. Such was the condition in which the granule-cells presented themselves in the blood of fresh mussels. In the blood of mussels which had been kept for some days in the house without food or change of water, but still alive though weak, the granule-cells were found, for the most part, to continue uniformly distended after the blood was drawn, their cell-wall not shooting out into processes (figs. 4 and 5.). The contents appeared at the same time more broken up into granules. In this state the size of the cells was from $\frac{1}{1800}$th to $\frac{1}{2000}$th of an inch in diameter. They appeared in both coarsely and finely granular stages.

76. Cells in which the nucleus is already distinctly visible without the application of any reagent, were few in number in the blood of perfectly fresh mussels, but in the blood of mussels which had been kept some days, they presented themselves in considerable numbers (figs. 9, 10, 11 and 12.).

77. The corpuscles in which a nucleus had thus become distinctly visible were, as they occurred in the blood of fresh mussels, distinguished by the following characters:—Circular but sometimes ovoid, somewhat prominent in the middle, with a uniform and strongly marked contour, of an opaline aspect, and measuring on an average about $\frac{1}{2400}$th of an inch in diameter, many being both smaller and larger (figs. 6 and 7.).

78. By the action of water the contents of these corpuscles, previously homogeneous looking, adherent to the cell-wall, and concealing the nucleus, became broken up into granules, so that the cell-wall and a nucleus came more or less distinctly into view, with characters similar to those presented by them after the animals had been kept some time as above mentioned, and which I now proceed to describe (fig. 8.).

79. The cell was generally circular but sometimes oval, and its wall did not shoot out into processes. It measured on an average $\frac{1}{2400}$th of an inch, some more, some less.

80. The nucleus was circular or oval. In the former case it measured about $\frac{1}{3600}$th of an inch in diameter, in the latter, the mean of the two diameters was on an average the same as this. Some were much elongated but narrow, others short but broad.

81. The circular cells had the nucleus either circular or oval, but when the cell was oval the nucleus was oval also, and usually elongated and narrow. Sometimes the oval nucleus appeared almost free, the cell-wall very much contracted, being attached to one side only.

82. In addition to the corpuscles now described, there were observed corpuscles very pale and few in number, apparently the nuclei of the nucleated cells become free and in process of disappearing.

83. Lastly, there was a great number of elementary granules; the larger, of the form of biconcave circular discs, measuring on an average $\frac{1}{6000}$th or $\frac{1}{7000}$th of an inch in diameter, less or more.

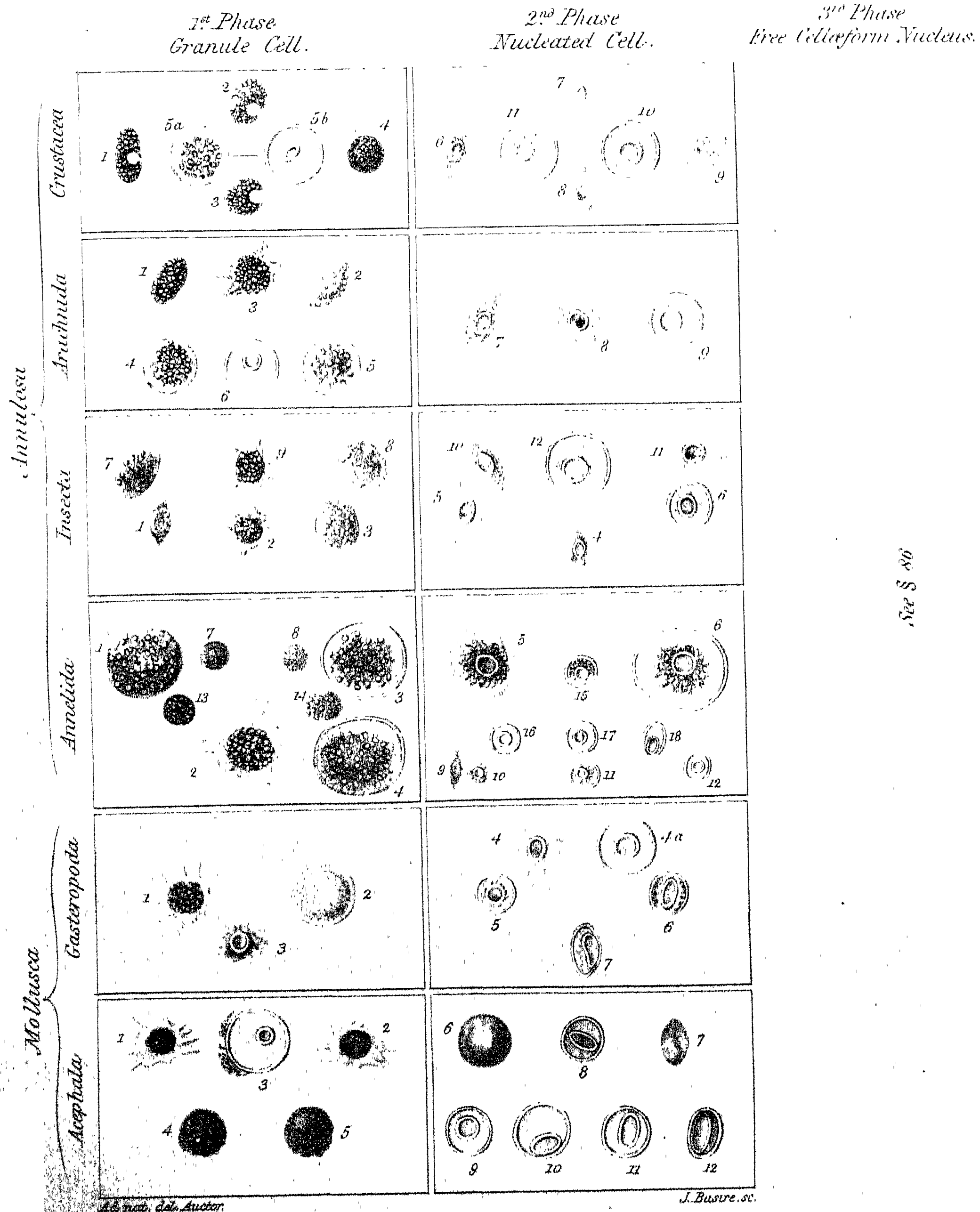
84. It thus results that in all the invertebrate animals in which the blood has now been examined, the blood-corpuscle presents itself in the phases of granule-cell and of nucleated cell; that in the phase of granule-cell it occurs in more or less well-marked coarsely and finely granular stages; that in the phase of nucleated cell it occurs in the uncoloured stage; but that as regards a coloured stage, though such cannot be said to be altogether wanting in some of the animals, the coloration of the cell is in a very slight degree. The cellæform nucleus is found more frequently and more decidedly coloured.

85. It also results that corpuscles exist in transition from the phase of granule-cell to that of nucleated cell.

86. It farther results that corpuscles occur in the blood of some of the animals, which appear to be the nuclei of the nucleated cells become free. Such, however, are to be viewed as abortions rather than as examples of a third phase, or phase of free cellæform nucleus.

87. Lastly, it results that corpuscles are met with in greater or less numbers belonging to the category of the lowest forms of organic elements, viz. elementary

The Blood corpuscle in its different Phases of development in Invertebrate Animals.



Ad nat. del. Auctor.

J. Basire sc.

See § 86

N.B. All the objects here delineated are magnified 550 diameters.
The microscope a compound one by Ross. — the object glass 1/8th inch.

EXPLANATION OF THE PLATE.

PLATE II.

ANNULOSA.

CRUSTACEA.—CRABS.

First Phase.—Granule-cell.

Fig. 1. Granule-cell as it appears when the blood is examined immediately on being drawn.

Figs. 2 and 3. Granule-cells changed in shape as they appear very soon after the blood has been drawn.

Fig. 4. Granule-cell, with the cell-wall in view at the circumference, and shooting out bud-like processes here and there.

Fig. 5 *a*. Granule-cell after being acted on by water.

Fig. 5 *b*. Granule-cell after being acted on by acetic acid. The granules have all disappeared by solution, and a small cellæform nucleus has thus come into view.

Second Phase.—Nucleated Cell.

Fig. 6. Nucleated cell as it appears when the blood is examined immediately on being drawn.

Figs. 7, 8, 9. The nucleated cell in different degrees of change of shape.

Fig. 10. Nucleated cell after being acted on by water.

Fig. 11. Another, after being treated in the same way, but still presenting some remains of the granules of the first phase, and a smaller cellæform nucleus than the preceding.

ARACHNIDA.—SPIDER.

First Phase.

Fig. 1. Granule-cell, coarsely granular stage.

Fig. 2. Granule-cell, finely granular stage; both as seen when the blood was examined immediately on being drawn.

Fig. 3. Granule-cell changed in shape, and with the cell-wall shot out into processes.

Figs. 4 and 5. Granule-cells in coarsely and finely granular stages distended by water.

Fig. 6. Granule-cell after the granules have been dissolved by acetic acid.

Second Phase.

Fig. 7. Nucleated cell as it appeared when the blood was examined immediately on being drawn.

Fig. 8. The same, changed in shape, as it appeared soon after the blood was drawn.

Fig. 9. The same, distended by water.

Insecta.—Beetle.

First Phase.

Fig. 1. Granule-cell as it appeared when the blood was examined as soon as possible after being drawn.

Fig. 2. The same, changed in shape—the cell-wall shot out into processes—as it appeared soon after the blood was drawn.

Fig. 3. The same, after the action of water.

Second Phase.

Fig. 4. Nucleated cell, as it may sometimes be seen when the blood is examined immediately on being drawn.

Fig. 5. The same cell, changed in shape. The cell-wall extremely pale, shrivelled, and shot out here and there into processes.

Fig. 6. The same, distended by water.

Insecta.—Chrysalis of Cabbage-butterfly.

First Phase.

Figs. 7 and 8. Granule-cells in coarsely and finely granular stages.

Fig. 9. Granule-cell, with the cell-wall shot out into processes.

Second Phase.

Fig. 10. Nucleated cell of its original shape.

Fig. 11. The same, with the cell-wall shrivelled and shot out into processes.

Fig. 12. The same, distended by water.

Annelida.—Earth-worm.

First Phase.

Fig. 1. Granule-cell, coarsely granular stage. The cell-wall shot out into a single bud-like process.

Fig. 2. Granule-cell, finely granular stage. The cell-wall shot out into cilia-like processes.

Figs. 3 and 4. The same cells distended by water.

Second Phase.

Fig. 5. Nucleated cell with its cell-wall shot out into processes.

Fig. 6. The same, distended by water.

Annelida.—Medicinal Leech.

First Phase.

Figs. 7 and 8. Granule-cells.

Second Phase.

Fig. 9. Nucleated cell as seen when the blood is examined immediately on being drawn.

Fig. 10. The same, changed in shape, as it appeared soon after the blood is drawn.

Figs. 11 and 12. Nucleated cells distended by water.

Blood vomited by Medicinal Leech.

Figs. 13 and 14. Granule-cells, coarsely and finely granular stages.

Fig. 15. A transition cell.

Figs. 16, 17 and 18. Nucleated cells.

MOLLUSCA.

GASTEROPODA.—WHELK.

First Phase.

Fig. 1. Granule-cell, with the cell-wall shot out into processes.

Fig. 2. The same, distended by water.

Fig. 3. The contents and nucleus of the same, set free by the bursting of the cell-wall.

Second Phase.

Fig. 4. Nucleated cell, with the cell-wall shot out into processes.

Fig. 4 *a*. The same, distended by water.

Figs. 5, 6 and 7. Nucleated cells, the cell-wall of which did not shoot out into processes.

ACEPHALA.—MUSSEL.

First Phase.

Figs. 1 and 2. Granule-cells, coarsely and finely granular stages, with the cell-wall shot out into processes.

Fig. 3. Granule cell after the action of water.

Figs. 4 and 5. Granule-cells from a mussel which had been kept some time in the house.

Second Phase.

Figs. 6 and 7. Cells from the blood of fresh mussels, by the action of water on which a nucleus has been rendered visible, as in fig. 8.

Figs. 9, 10, 11, 12. Nucleated cells found in considerable number in the blood of mussels kept some time, but few in number in fresh mussels.

VI. *The Blood-corpuscle considered in its different Phases of Development in the Animal Series. Memoir* III.—*Comparison between the Blood-corpuscle of the Vertebrata and that of the Invertebrata.* *By* T. WHARTON JONES, *F.R.S., Lecturer on Anatomy, Physiology and Pathology, at the Charing-Cross Hospital, &c.*

Received May 7,—Read June 19, 1845.

1. IN instituting a comparison between the blood-corpuscle, in its different phases of development, of the Vertebrata and that of the Invertebrata, it is obvious that the examples first taken for the purpose ought to be selected from the lowest class of the oviparous Vertebrata on the one hand, and from the highest class of the highest division of the Invertebrata on the other.

2. In accordance with this I proceed to compare together the blood-corpuscles of the Skate and Crab.

Comparison between the Blood-corpuscle of the Skate and that of the Crab.

3. From the observations above related, it results that the blood-corpuscle of the Crab resembles that of the Skate in presenting two different phases of development, viz. the phase of granule-cell and the phase of nucleated cell, and that in these two phases respectively the essential points of structure are the same.

4. The blood-corpuscle of the two animals, however, differs in the degree of development which it attains in the phase of nucleated cell. In the Crab its development is arrested at the uncoloured stage, or at the most at the commencement of the coloured stage. But this absence of nucleated cells in the decided coloured stage in the blood of the Crab, it has been seen is a peculiarity which there is reason to believe is presented by one at least from among oviparous vertebrate animals, viz. *Branchiostoma lubricum.*

5. The blood of this fish may therefore be admitted as probably differing but little in the character of its corpuscles from the blood of the Crab, and as constituting in this respect a transition from the Vertebrata to the Invertebrata.

6. Having thus compared the blood-corpuscle of an animal from the lowest class of oviparous Vertebrata with that of one from the highest class of the highest division of the Invertebrata, we are prepared to institute a comparison between the blood-corpuscle of the oviparous Vertebrata generally, and that of the Invertebrata from Crabs to Mussels.

Comparison between the Blood-corpuscle of the oviparous Vertebrata generally, and that of Invertebrata.

7. In the oviparous Vertebrata, from the Skate upwards, it has been seen that the blood-corpuscle in its different phases of development is essentially similar to that of the Skate. In the Invertebrata, from the Crab down as far as we have gone, it has also been seen that the blood-corpuscle in its different phases of development is essentially similar to that of the Crab. The only difference therefore in essential respects between the blood-corpuscle of the oviparous Vertebrata generally and that of the Invertebrata, is the same as that between the blood-corpuscle of the Skate and Crab, viz. that in the phase of nucleated cell, the latter does not attain to a decidedly coloured stage.

8. Hitherto I have altogether excluded the blood-corpuscle of the Mammifera from comparison with that of the Invertebrata; but such comparison I now proceed to make.

Comparison between the Blood-corpuscle of Mammifera and that of Invertebrata.

9. In the phase of granule-cell, the blood-corpuscle of the Mammifera and that of Invertebrata resemble each other in essential points of structure. In the phase of nucleated cell they also agree in the absence of a decided coloured stage; in this respect differing from the blood-corpuscle of the oviparous Vertebrata generally and of the early mammiferous embryo.

10. But here the resemblance between the blood-corpuscle of the Mammifera and that of the Invertebrata ceases. In common with the blood-corpuscle of the oviparous Vertebrata, that of the Invertebrata differs from the blood-corpuscle of the Mammifera in not attaining to a decided third phase. The free cellæform nuclei which appear to exist in the blood of some of the Invertebrata, it has been above stated, can only be considered as abortions of such a phase*.

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* From neglecting the precautions above observed in instituting a comparison between the blood-corpuscles of the Vertebrata and those of the Invertebrata, Mr. NEWPORT, in a communication recently made to the Royal Society, appears to me to have fallen into a very serious error, as to what corpuscles in the blood of insects and other Invertebrata are analogous to the "red blood-corpuscles" of the Vertebrata.

Overlooking altogether even the well-known differences between the "red blood-corpuscles" of the Mammifera and those of the oviparous Vertebrata, he assumes the "red blood-corpuscle" of the Mammifera as a standard by which to recognise in the blood of insects and other Invertebrata, any corpuscles which may be the analogues of the "red blood-corpuscles" of the Vertebrata generally.

Accordingly, finding in the blood of insects the elementary granules described in Memoir II. of this series of papers, pars. 19, 27, 36, 38, &c., and not being acquainted with the true nature of such particles, he has been misled by their similarity to his assumed type of "red blood-corpuscles," especially in respect of outward form, which is that of biconcave circular discs, into the conclusion that they are the analogues of the "red blood-corpuscles" of the Vertebrata.

The corpuscles in the blood of insects and other Invertebrata which, though little or not at all coloured, I have

11. It was at one time supposed that the red colour of the "red blood-corpuscles" of the Vertebrata is dependent on the iron which they contain, but latterly chemists have come to the conclusion, that though iron is essential to the "red corpuscles," it is not so to their colouring matter.

12. In reference to this question, it occurred to me that it would be interesting to ascertain whether the corpuscles of the blood of an invertebrate animal, notwithstanding their slight degree or total want of colour, contain iron.

13. Accordingly I collected some of the corpuscles of the blood of the Crab, which it is easy to do in consequence of the mode in which they collect together after the blood is drawn, as described in Memoir II. of this series, and in consequence of the plasma not coagulating. These I dried carefully and sent to my friend Professor GRAHAM, who was so kind as to undertake to test them for iron.

14. The annexed letter, from Mr. GRAHAM, will show that the blood-corpuscles of the Crab, though but slightly coloured, do contain iron.

"DEAR JONES,

"I should have communicated sooner the result of the examination of the white corpuscles of the blood of the Crab, of which you sent a small quantity in a dried state, amounting to two or three tenths of a grain. It is that they contain a sensible quantity of iron, perhaps as much as red corpuscles.

"Yours, dear Sir,
"Most truly,
"THOMAS GRAHAM."

"*University College, Nov.* 29, 1844."

15. Of course the presence of iron in the corpuscles of the blood of the Crab is not alone a proof that the red colour of the "red corpuscles" of the blood of the Vertebrata is not owing to iron; it is merely a proof that iron in equal quantity may exist in corpuscles without imparting to them a decided red colour, such as is presented by the "red corpuscles" of the blood of the Vertebrata[*].

Comparison of the Corpuscles of the Blood of the Invertebrata with the Corpuscles of the Lymph of the Vertebrata.

16. In the very respect in which the blood of the Invertebrata differs from that of the oviparous Vertebrata generally, viz. the absence of nucleated cells in the decidedly coloured stage, it resembles their lymph[†] (Memoir I., pars. 101 to 105.).

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shown to be the true analogues of the "red blood-corpuscles" of the *oviparous* Vertebrata, viz. the nucleated cells, Mr. NEWPORT considers to be an early stage of the corpuscles which I have described in the same blood under the name of granule-cells, the former, according to him, becoming the latter by the development and accumulation of granules in their interior.

When thus filled with granules, the cells, he appears to believe, burst, and the granules, thus set free, become the alleged analogues of the "red corpuscles" of the Vertebrata.

[*] The coloured plasma of the blood of the Crab gave unquestionable indications of iron.

[†] This conclusion, it is to be particularly observed, is to be distinguished from a view first promulgated by

To complete the history of the blood-corpuscle, it remains to inquire into the first formation of the granule blood-cell on the one hand, and into the ultimate fate of the nucleated blood-cell of the Invertebrata, and of the oviparous Vertebrata, and of the free cellæform nucleus of Man and the Mammifera on the other; and also to collate the views given of the development of the blood-corpuscle with the theory of cell development in general.

In executing this task I shall have an opportunity of considering several questions which have suggested themselves in the present series of papers, but which it would have been premature to have entered upon.

Professor Rudolph Wagner, viz. that the corpuscles of the circulating fluid of the Invertebrata are not any of them analogous to the red blood-corpuscles of the Vertebrata, but are all of them analogous to the corpuscles of the lymph, or chyle merely, and that therefore the circulating fluid of the Invertebrata is "mere chyle, not proper blood," proper blood being, as he defines it, "a red coloured fluid containing characteristic corpuscles."

This view appears to me to be distinction without essential difference, and to have arisen,—1st, from an imperfect acquaintance with the corpuscles of the lymph of the Vertebrata, and their relationship to those of the blood of the same division of animals on the one hand, and with the corpuscles of the circulating fluid of the Invertebrata on the other; 2ndly, from laying too much weight on the presence or absence of colour as a distinctive character; thus making no distinction between the "red corpuscle" of the blood of the Mammifera, and the "red corpuscle" of the blood of the oviparous Vertebrata in consequence of their similarity in colour, though there is between them an essential organic difference; whilst between the "red corpuscle" of the blood of the oviparous Vertebrata and the nucleated cell of the circulating fluid of the Invertebrata, in consequence of a supposed total absence of colour in the latter, a decided distinction is made, though there is, in fact, between them no essential organic difference.

Waiving, however, the organic difference between the "red corpuscle" of the Mammifera and the "red corpuscle" of the oviparous Vertebrata, and the organic resemblance between the "red corpuscle" of the oviparous Vertebrata, and the little or not at all coloured nucleated cell of the circulating fluid of the Invertebrata, I would observe in regard to the presence or absence of colour, that nothing bearing on the question can be inferred from it, even in a physiological point of view, seeing that the nature and use of the red colouring matter of the "red blood-corpuscles" are as yet too little known.

The colour of "red blood-corpuscles" is now acknowledged not to be owing to the iron entering into their composition, and therefore it is not, as has been supposed, a manifestation of the existence of any endowment which may be possessed by the "red corpuscles" by virtue of the iron which they contain. But even if this had been so, the fact above mentioned, of the presence of iron in the uncoloured or but little coloured corpuscles of the blood of the Crab, renders it extremely probable that what endowment soever may be possessed by the "red corpuscles" of the Vertebrata by virtue of the iron which they contain, may be equally possessed by the corpuscles of the blood of the Crab.

Professor Wagner adduces arguments of another kind in corroboration of his view, that the circulating fluid of the Invertebrata is "mere chyle, not proper blood;" but which it is scarcely necessary to notice after what I have just said, especially as their force, so far as it is evident, appears to bear more against than in favour of his view.

VII. *On a point connected with the dispute between* KEIL *and* LEIBNITZ *about the invention of Fluxions. By* A. DE MORGAN, *Esq., F.R.A.S., &c. Communicated by* S. HUNTER CHRISTIE, *Esq., Sec. R.S., &c.*

Received November 27, 1845,—Read January 29, 1846.

THOSE who have consulted the records of the Society for purposes of history, have omitted to find, or at least to notice, an addition made to the Committee appointed to decide between KEIL and LEIBNITZ, between the commencement of its labours and the presentation of its report. Singularly enough this omission makes NEWTON appear to assert a positive falsehood, in a matter of which he must have had accurate knowledge, and as to which the position of President gave him every opportunity of refreshing his memory.

The real facts are, that on the 6th of March 1711–12, a Committee was appointed to inspect the Archives, consisting of ARBUTHNOT, HILL, HALLEY, JONES, MACHIN, and BURNET: and that further, ROBARTS, a contributor to the Transactions, was added on the 20th, BONET, the Prussian minister, on the 27th, and DE MOIVRE, ASTON, and BROOK TAYLOR on the 17th of April. Of these newly-added members, BONET and DE MOIVRE were aliens. All the historical writers who enumerate the Members of the Committee, say nothing about the additions, but confine their list to the six gentlemen first named, that is, to the original Committee.

Now NEWTON, in his letter to CONTI of February 26, 1715–16, first published at the end of the English edition of RAPHSON's History of Fluxions, asserts that the materials of the *Commercium Epistolicum* were "collected and published by a *numerous* Committee of gentlemen *of different nations,* appointed by the Royal Society for that purpose."

Whether a Committee of six is properly called numerous may be a question; but there can be no doubt that knowingly to have styled ARBUTHNOT, HILL, HALLEY, JONES, MACHIN, and BURNET, a committee of gentlemen of different nations, would have been, if not a direct falsehood, at least the pitiful evasion of treating the four races of the United Kingdom as four different nations with reference to a dispute between an Englishman and a German. As to this, it is material to remember that the names of the Committee had never been published, nor does NEWTON give them in the place cited. If any one should say that MACHIN's name might have looked rather French to an Englishman, it might be answered that NEWTON must have known JOHN MACHIN of Gresham College, whom he was constantly in the habit of seeing, to have been as much a Briton as himself. And in fact, MACHIN looks so little like a French name, that Laplace once spells it Mechain, meaning Bradley's friend, not his own contemporary. In this state, owing to the accidental omission of the additions made to the Committee, the evidence of Newton's veracity was left: and considering the number of insinuations made by the partizans of the English side of the dispute against the moral character of Leibnitz, there can be little doubt that continental writers on the other side would have hit this apparent blot, if they had been able to see it. An accidental passage in a memoir of De Moivre led me to suspect the omission above described: and the Assistant Secretary, on my application, was good enough to examine the records of the time and to supply it. The biography to which I allude is the "Mémoire sur la vie et sur les écrits de Mr. Abraham De Moivre....par Mr. Maty. A la Haye, de l'imprimerie de H. Scheurleer, F. Z." (12mo, no date). This Mr. Maty must have been Dr. Matthew Maty, who, as well as his son, was a secretary of the Society. He was the intimate friend of De Moivre, and he mentions Dr. Birch as having consulted the registers of the Society for him on different points. He states that De Moivre was appointed on this committee on the 17th of April (the true date), and gives *all* the names. He also states that this transaction drew De Moivre out of the neutrality which till then he had observed. It is remarkable that Maty thus intimates that the mere fact of joining the Committee was destruction to the character of a neutral. And Burnet himself, a member of the Committee, is stated by John Bernoulli (in his correspondence with Leibnitz) to have written a letter to him, giving him the information that the Royal Society was engaged in proving that Leibnitz might have seen certain letters of Newton, &c. These slight things tend to show that the Committee in question was thought at the time not to be a judicial body, but one of avowed partizans: and it is, I think, necessary for the character both of the Committee and the Society, that this truth, as I believe it to be, should be acknowledged. On any other supposition than that the Committee was meant to be Newtonian, for the defence (through Keil) of Newton, and not for the decision of the question, it would be difficult to explain with credit to the parties concerned, the selection of Arbuthnot, Burnet, and Aston, friends of Newton, but not known as mathematicians; or of Brook Taylor, a Fellow of a few days standing, who had then published nothing, and was only known to the Society, or chiefly known, by his private correspondence with Keil, the nominal defendant. There may have been, and I often suspect there was, something of truth in the surmise of Leibnitz, who thought that the near prospect of the Hanoverian succession created some dislike against the subject and servant of the obnoxious Elector in the minds of the Jacobite portion of English science. "Amicus Anglus ad me scribit," says Leibnitz, "videri [eos qui parum Domui Hanoveranæ favent] aliquibus non tam ut mathematicos et Societatis Regiæ Socios in Socium, sed ut Toryos in Whigium quosdam egisse." I am unfortunate enough to differ from the general opinion in England as to the manner in which Leibnitz was treated, and this after much examination: I am therefore the better qualified to call the attention of the Society to the groundlessness of the charge which might, from an accidental omission, have been made against NEWTON's veracity; and I am glad it has fallen to me to do so.

I can hardly find any notice of this little tract of Dr. MATY. Had it been much known I cannot but suppose that the following phrase of NEWTON would have obtained some currency: the English parenthesis, and the italics, are MATY's, not mine. "Comme tout ce qui regarde les grands hommes peut être intéressant, on sera peut-être bien aise de savoir que NEWTON a souvent dit à Mr. de MOIVRE que s'il avoit été moins vieux il auroit été tenté de revoir sur les dernières observations sa théorie de la Lune, ou comme il s'exprimoit *de l'attaquer de nouveau* (*to have another pull at the moon*). Je tiens ceci de Mr. de MOIVRE lui-même."

There is also an interesting fact concerning DE MOIVRE, which is little, if at all, cited. Happening one day to have to call on the Earl of Devonshire, he met a man whom he did not know coming out of the house. This man was NEWTON, who had come to present a copy of the *Principia*, and had left it in the antechamber in which DE MOIVRE had to wait till the Earl was ready to see him. He opened the book, and found to his surprise, that, strong as he knew himself to be, he could only just manage to follow the reasoning. He immediately procured a copy; but as he was employed all day in walking about London from one pupil to another, the only way in which he could read it was by tearing leaf after leaf, and carrying a few at a time in his pocket to look at in his walks and in other intervals.

It cannot be necessary to remind the Society that the subject of this paper may possibly not be the only case in which their records would furnish information on points of history which have hitherto been overlooked. These records are a most important part of the progress of science in England: and I have often regretted that the example set by Dr. BIRCH has found no follower among those who can appreciate the value of minute information.

VIII. *On the Action of the Rays of the Spectrum on Vegetable Juices. Extract of a Letter from Mrs.* M. Somerville *to Sir* J. F. W. Herschel, *Bart., dated Rome, September* 20, 1845. *Communicated by Sir* J. Herschel.

Received November 6,—Read November 27, 1845.

In the following experiments the solar spectrum was condensed by a lens of flint glass of 7½ inches focus, maintained in the same part of the screen by keeping a pin-hole, or the mark of a pencil constantly at the corner of the red rays, which were sharply defined by using blue spectacles to protect my eyes from the glare of light, and the apparatus was covered with black cloth in order to exclude extraneous light.

Thick white letter paper, moistened with the liquid to be examined, was exposed wet to the spectrum, as the action of the coloured light was more immediate and more intense than when the surface was dry. As I had not access to the morning sun, the observations were made between noon and three in the afternoon.

The lavender rays came vividly into view under a condensed spectrum on white paper washed with a solution of sulphate of quinine in dilute sulphuric acid: they were narrow, and their length, by rough measurement, was equal to the distance between the upper edge of the violet and the lower edge of the blue. They were very brilliant on black silk or other dark surfaces, and invariably of lavender colour; and even on paper stained with turmeric, the pale yellow rays which you had observed, were tipped with lavender on being washed with this liquid, though its duration was momentary, as it vanished as the surface became dry; but they were permanent in other instances.

The lavender rays change their colour with a change of the liquid, for instance they are lavender coloured on nitrate of silver discoloured by light to a very pale brown, washed with a solution of sulphate of quinine in dilute sulphuric acid; whereas, on a similar surface of pale brown nitrate of silver, washed with the juice of the petals of pale blue *Plumbago auriculata* in distilled water, to which sulphuric acid was added, they appeared of a vivid apple-green, and acquired a tip of lavender colour on the surface being washed with a solution of sulphate of quinine in dilute sulphuric acid of considerable strength; the effect, however, was transient. After several unsuccessful attempts to repeat this experiment next day, I at length discovered that its success depended upon the acid being strong enough to decompose the juice and give it a reddish orange hue; and even then the rays are not vivid till the paper has been frequently washed with the juice and become nearly dry; and the experiment is more successful when the liquid has been kept a night. The action of the surface in changing the colour of the lavender rays may be illustrated by passing the spectrum over paper coated with nitrate of silver brought to a clear yellow-brown by exposure to the sun; one half being washed with the liquid in question, and the other half with a solution of sulphate of quinine in dilute sulphuric acid, on the first half the lavender rays became vivid apple-green, while on passing to the other half they instantly change to an equally vivid lavender colour. These rays often darken the surface throughout their whole length; sometimes they acquire a powerful bleaching action, and sometimes they have no effect, as evidently appears from the following experiments.

There was reason to suspect that the action of the spectrum at the junction of the lavender with the violet rays, is in some cases different from what it is on either of these colours separately, a second dark image having appeared at the extremity of that which terminated with the violet, indicating a break in the continuity of action and giving the idea of a secondary spectrum.

The juice of fresh-gathered petals of double flowering pomegranate in alcohol afforded an example of this. Paper washed with this juice became rich crimson, and on being exposed wet to the condensed spectrum, a narrow line of deep crimson was formed at the junction of the green and yellow rays, or perhaps in the most refrangible yellow, surrounded by a whitish lozenge-shaped border (Plate III. fig. 1.). On again washing with the juice, instead of the white border, which had vanished, there was a crimson flame-shaped image, curved at the lower edge of the yellow rays and tapering upwards to the violet. Its colour was darker than that of the ground, though paler than the narrow line, which maintained its intensity; and although the latter increased in width, it did not become as broad as the image in question. At the upper end of the violet another little dark image was formed, apparently owing to the action of the lavender rays, having exactly their form. The orange and red rays, especially the red, had no effect, though at the distance of about half the length of the spectrum beyond the red, two distinct spots were formed of deep crimson, which I believe to be the heat spots which you discovered. After some time, a bleaching appearance surrounded the whole image from the red upwards, probably owing to rapid evaporation from the heat of the spectrum (fig. 2.). Exterior bleaching frequently took place in the course of the experiments, permanent in some instances, while in others it vanished as the surface dried. When water was used with the juice instead of alcohol, the general character of the image was similar to that described, except that the small figure beyond the violet was more distinct, and seemed to bear the same proportion to that formed by the rest of the spectrum which the length of the lavender rays bears to the length of the sum of the others. The bleached part round the whole was more extended, and a faint crimson haze encompassed the dark spots, which were very distinct (fig. 3.).

This experiment is one of many instances in which I have observed the powerful

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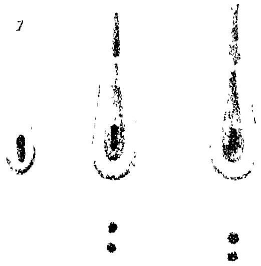
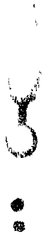

Pomegranate

4


Globe Amaranthus

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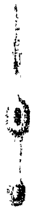
Plumbago Auriculata

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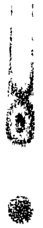
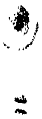

Beet juice with salt

7


Beet juice with water.

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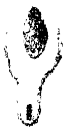
Beet juice with acid

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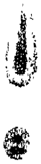
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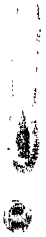
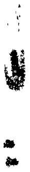
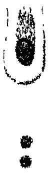

Nasturtium.

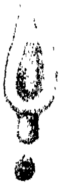
11


Scarlet Geranium

12


Scarlet Geranium with acid.

13


Scarlet Balsam with acid.

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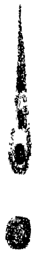
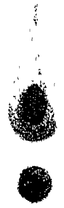
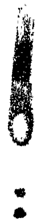

Dahlia juice. with water

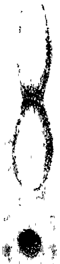
15


Dahlia juice with acid.

16


Scarlet Geranium, j with Carbonate of S

17


Dahlia with salt, quinine & Nitric acid.

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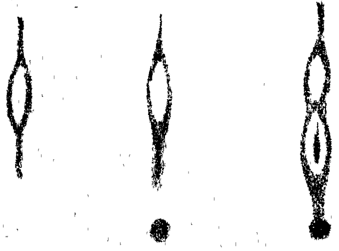
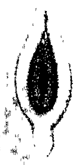

Scarlet Zinnia in distilled water.

21


Walnut juice.

22

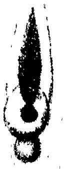


Fig juice

influence of the yellow and green rays upon vegetable substances, an influence which seems to be unconnected with heat, since the darkening generally was least under the red rays, and immediately below them, where the calorific rays are most abundant. I found that the action of the rays of mean refrangibility on vegetable juices was much increased by the addition of a little sulphuric acid. In most cases this powerful influence was simultaneous with the appearance of two dark spots below the visible spectrum, sometimes sharply defined, sometimes in the centre of a disc of a paler hue; and in some instances the disc was seen without spots, though it rarely happened that they did not appear under one or other of these forms.

The following are some of the cases in which the simultaneous effect was produced: for example, paper washed with juice of the petals of *Globe amaranthus* in distilled water, on exposure to the spectrum acquired a delicate pink tint, which was soon bleached to whiteness, from the upper edge of the green to the end of the lavender rays, while at the same time a perfectly circular spot of equal whiteness was seen under the red rays, and a little way below them, which had the appearance of being an image of the sun. After more washing with the juice, the two bleached parts were united by a long white neck, which speedily vanished, and was succeeded by a dark crimson image, whose greatest intensity of colour was under the yellow rays. At some distance below the red rays, two crimson spots were strongly marked, especially the uppermost, both surrounded by a paler halo (fig. 4.).

The juice of the petals of pale blue *Plumbago auriculata* in distilled water imparted its tint to writing-paper, which, after exposure to the action of diffused light, acquired a pale yellowish green hue. The part under the lavender and violet rays of the spectrum, repeatedly washed with the juice, assumed a pale brown colour: the indigo rays seemed to have no effect, although from their lowest edge to the distance of half the length of the spectrum below the red rays, a lavender blue image was formed. Under the orange rays a minute indigo-coloured spot appeared, and also a larger spot of the same colour under the yellow, which were soon blended into one, forming a single oblong figure of maximum intensity, surrounded by a halo of paler indigo (fig. 5.). An insulated disc of the same colour as the halo, with two dark spots in its centre, appeared at some distance below the red rays. The juice of this plant is easily decomposed; by the addition of sulphuric acid it became a delicate pinkish grey, which was also the colour of paper wetted with it, while under the spectrum a pale yellow figure of considerable width was impressed, extending under the whole of the visible rays, and soon after a deep yellow image with a paler halo was seen in its centre. The halo or paler part of the image lay between the red and the end of the lavender rays, while the deep yellow, or perhaps more properly the yellow-brown figure, extended under the yellow-green and blue rays, the maximum of breadth and of colour lying in the yellow and green. Two insulated spots of the same yellowish-brown in the centre of a yellow disc were formed below the visible spectrum, and the whole surface soon became bright yellow from the action of the scattered light, consequently the extensive pale figure was obliterated, leaving only the interior dark image with its halo and the spots with their disc permanent.

The juice of beet-root in a strong solution of common salt imparted a pink colour to the paper, and the most refrangible rays acquired a powerful bleaching energy. The pink ground was whitened under the lavender, indigo and blue; a deep crimson spot was formed under the yellow, with a rose-coloured halo elongated to the bleached part on one side, and to the end of the orange on the other, while a hazy rose-coloured disc was visible at a distance below the red (fig. 6.). The crystallization of the salt on this figure was in proportion to the intensity of colour; most on the crimson spot and its halo and on the coloured disc, but scarcely any on the bleached portion.

A solution of hyposulphate* of potash in the beet-juice had nearly the same effect as the salt, only that the dark spot with its halo was more extended, and the latter formed a long neck beyond the red, ending in a deep rose-coloured disc. The appearance was precisely similar when muriate of ammonia or iodide of potassium was used, I therefore inferred that the alkali imparted the bleaching property to the most refrangible rays.

Paper washed with the juice of beet-root in distilled water assumed a fine rose-colour, on which a figure was bleached by the spectrum, wide and rounded in the yellow, but tapering upwards: after another wash, a dark crimson image was formed in its centre reaching to the blue, with a still darker spot under the yellow. The red rays had no effect, below which at the usual distance two indistinct spots appeared. A drop of sulphuric acid in the juice changed the tint of the paper to a purple colour, on which, after various alternations of bleaching and darkening, the spectrum impressed a dark figure, broad and rounded on the yellow, and tapering to the blue, beyond which there was scarcely any action (fig. 8.). The whole was surrounded by a broad pale border, stretching in a neck far beyond the red, with an indefinite dark line in its centre.

In these experiments almost the only part of the visible spectrum that darkened the surface was that of mean refrangibility, but even when the whole had that effect, the maximum was generally produced by the rays in question, the insulated spots, or some indication of them, appearing at the same time. This was the case with the juice of *Amaranthus caudata*, which stained white paper rose-colour, and the spectrum impressed a deeper rose-coloured image from the lowest edge of the red to the end of the blue, with a dark crimson oval figure under the yellow and green, while two insulated crimson spots appeared in a rose-coloured halo below.

White paper washed with the juice of rose-coloured verbena in distilled water assumed a lemon-colour (fig. 9.), while the spectrum impressed a pale rose-coloured image from the lowest edge of the red to the end of the indigo rays, in the centre of which, under the green, yellow, and part of the orange rays, a narrow figure of very deep crimson was formed, and two rose-coloured spots appeared in a rose-coloured disc below the red.

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* *Sic in MS.* but probably meaning hyposulphite, a salt in common use in photographic research, which the hyposulphate is not. The two salts have totally different properties. The mistake is a very common one —

Dark orange-coloured nasturtium stained writing-paper the colour of prussian blue, the image impressed on which was a deeper shade of the same, extending from the lowest edge of the red to the end of the blue, while a still deeper tint appeared under the orange, yellow and green, with a point of maximum intensity in the lowest part of the yellow. There was a tendency to bleaching from the blue upwards, and below the other end of the spectrum two well-defined dark spots were surrounded by a paler blue penumbra (fig. 10.).

The juice of the velvety petals of a scarlet geranium was very sensible to the action of light (fig. 11.), and stained white paper rose-colour. A deeper rose-coloured tint was impressed by the spectrum from the lowest edge of the red to the end of the blue, feeble in the red and deeper in the orange, while a crimson image extended from the zero point in the yellow to the end of the green; the maximum of intensity was in the latter. Two crimson-coloured spots in a rose-coloured halo were strongly marked at some distance below the red.

With the addition of acid this juice gave a scarlet tint to paper, and a darker scarlet image was formed from the middle of the yellow to the end of the indigo. Then a very dark scarlet oval appeared between the zero point and the upper edge of the blue, with a small point of maximum intensity on the upper part of the yellow. The orange and red rays had no effect, but a pale rose-coloured border surrounded the lower part of the figure, which became of a bluer tint and darker than the ground when dry. Two spots of scarlet were distinct at some distance below (fig. 12.).

The juice of the petals of scarlet balsam in distilled water is another instance; it gave a pale scarlet tint to paper, and a lake-coloured image extended throughout the spectrum from a point considerably above the violet to below the spots, which were distinctly visible, though not sharp. The greatest intensity of colour and breadth were under the yellow and green. When a little sulphuric acid was added to the same liquid, the action was feeble above the blue rays, but a very broad dark image was formed under the orange, yellow and green rays; possibly under part of the blue also, which gradually became nearly black, with a blackish red penumbra, surrounded by a broad border of bright scarlet of a deeper tint than the ground, passing under the blue and indigo at one end, and under the red at the other, while below the latter an indistinct appendage of a paler colour projected; an insulated scarlet disc appeared still lower down, in which two spots were evident, though not sharply defined (fig. 13.). The breadth of the image was very remarkable, and it was so deeply impressed that there was little difference in its intensity on the two sides of the paper. On repeating the experiment with a hot iron behind the paper, the figure was the same, only that the central part was brown and the border merely a paler shade of the same; a disc of the same colour as the border appeared below the red, which vanished the following day.

When the juice was extracted in alcohol instead of water, the action of the spectrum was somewhat different; the image extended from the lowest edge of the yellow to the end of the violet with three points of maximum intensity, the greatest in the yellow, the next in the green, and the last in the indigo. The red rays had no effect, but the spots, or rather their place was indicated. With water containing a little borax, there were only two points of greatest intensity, the first on the yellow, the other under the indigo and violet. Notwithstanding these differences the principal action was still in the rays of mean refrangibility, especially the yellow.

I have found no vegetable juice so sensible to light as that of the maroon-coloured or dark red dahlia in distilled water. It gave a lavender hue to white paper, while the part under a condensed spectrum became rapidly dark, from the edge of the orange to the end of the lavender rays, but with variable colour and intensity. A dark reddish oval was formed under the orange, yellow and green rays, with a narrow line of a still deeper colour in the centre of the yellow, while spots of less intensity and of a bluer tint appeared under the blue and violet rays, with some indication of another above; but these three points of inferior intensity were not always very distinct. At a little distance below the extreme red rays, two dark spots were formed in the centre of a hazy disc of reddish purple. A hot iron behind the paper occasioned no change in the figure, though it accelerated the action and increased its sharpness. In this and various other instances I found that repeated washing with diluted juice answered better than when it had a deeper colour (fig. 14.).

The addition of a little sulphuric acid to this juice accelerated the action of the rays of mean refrangibility, increased the intensity and breadth of the image, and changed the tint of the liquid to bright scarlet, which imparted its hue to white paper. Exposed wet to the spectrum a dark red figure by degrees appeared, extending from the upper edge of the orange to the end of the violet, in the midst of which a kind of oval of great intensity of colour was formed under the yellow and green rays, leaving a broad red border around. The red rays seemed to have little or no effect, though at some distance below them there were two dark spots on a dark haze. When the experiment was repeated with a hot iron behind the paper, the central image became almost black, and extended from the lowest edge of the yellow to almost the middle of the blue rays, while the dark crimson border passed under the orange at one end of the spectrum, ending at the indigo at the other, beyond which a pale crimson shade reached certainly to the end of the violet, and probably further, but it was so gradually shaded off that it was not possible to define its termination. There was a nebulous disc of pale crimson at some distance below the last visible red. This image, as well as that in the preceding experiment, were so deeply impressed that they penetrated the paper (fig. 15.).

Various other plants might be mentioned to show the peculiarly strong influence of the rays of mean refrangibility in darkening vegetable juices, and in this respect there seems to be a difference in the action of the spectrum on vegetable matter and metallic salts; it would however require a more extensive series of experiments to establish this point.

The very frequent recurrence of two insulated dark spots, or of some indication of them, is another peculiarity in the action of the spectrum on by far the greater number of vegetable juices which I have used. If these be identical with the heat spots discovered by you, there surely must be a difference in the nature of the calorific rays in the visible and invisible part of the spectrum, since these spots, or a darkish disc, often appeared when the red rays had little or no effect, or even possessed a powerful bleaching energy, as on the juice of the violet-coloured *Globe amaranthus*.

Since the simultaneous appearance of the insulated spots and the maximum intensity of darkening under the rays of mean refrangibility occurred so often, I am led to suspect a similarity, possibly identity, in the nature of the agent producing these phenomena. The greatest heat does not lie in the mean rays of the spectrum, nor does the greatest chemical action; and as you have shown that the parathermic rays are situate there, may not they be the cause of the phenomena in question, being also mixed with those rays of caloric which form the heat spots, and which I have no doubt are identical with the insulated spots in these experiments?

Some cases have occurred, and there may be many more, in which the maximum intensity was produced by those rays in which the chemical energy is most active, as for instance in the juice of *Coreopsis tinctoria*, which was darkened from the red to the end of the violet rays with almost equal intensity; the maximum, if there was any, lay under the blue and indigo; also the juice of the red and yellow variegated *Marvel of Peru*, which was darkened under the whole of the visible spectrum, the lavender rays excepted. But by far the greater number of vegetable juices which I have examined, were most affected by the most luminous rays.

The point of maximum intensity was sometimes altered by the addition of an acid or alkali, and sometimes by using alcohol instead of water; when a drop of acid was added to the juice of the crimson marvel of Peru, the greatest intensity of colour appeared under the indigo and blue, and a little carbonate of soda changed the point of greatest intensity from the yellow and green to the blue rays in the juice of *Plumbago auriculata*. A still greater change was produced on the juice of the scarlet geranium by the addition of carbonate of soda. The colour of the liquid was violet, but it stained the paper pale bluish-green. There was no action under the red rays, but a circular spot of a decided yellow colour was formed under the orange and yellow rays. A brownish tint was impressed by the green and blue, from the end of which up to the termination of the lavender rays, the ground assumed an inky colour of considerable intensity, with a strong maximum in the violet. At the usual distance below the red, two green spots appeared (fig. 16.).

The action of the different parts of the spectrum seems very capricious; for example, the most refrangible rays from the green to the end of the lavender darken some substances and bleach others. Instances of this bleaching action have been given in the juices of *Globe amaranthus* and *Plumbago auriculata*, both being bleached to whiteness by the rays in question. The red rays occasionally possess this property, as in the juice of the *Globe amaranthus*, those of mean refrangibility more rarely, yet an instance has already been given in the case of geranium juice with carbonate of soda; and another occurred when a drop of nitric acid, a little common salt, and sulphate of quinine were mixed with the juice of the dark red dahlia in distilled water. White paper repeatedly washed with this liquid acquired a tint of pale lilac, while the part under the spectrum was marked by a broad dark crimson image from the orange to the end of the violet. After another washing the paper was bleached to a very pale yellowish-white under the lavender and violet rays, while at a small interval below a second bleaching process began, and changed the interior of the dark image to a very pale reddish-yellow down to the beginning of the orange, leaving a dark crimson border on each side only, broadest and darkest under the yellow rays, and diminishing in width both up and down. Under the orange and red rays the surface acquired a pink tinge, and at some distance below, the same pink tinge formed a round hazy mark. Although the colours were very tender in this experiment they penetrated letter-paper, remaining unchanged many days (fig. 17.).

Singular changes were produced by the spectrum on the juice of the petals of the scarlet *Zinnia* in distilled water, which though not very sensible to the influence of light alone, became highly so on the addition of sulphuric acid. White paper washed with this liquid acquired a pinkish-grey tint, on which the first effect of the spectrum was a very broad dark image under the violet and indigo, with a long narrow appendage of the same inky tint going down to the end of the red, and also a dark shade upwards far beyond the violet. Being again washed with the liquid, the broad image under the violet and indigo was bleached white, leaving a dark margin (fig. 18.). The dark appendage then gradually became broader, the greatest intensity lying under the green and yellow, and a dark disc appeared below the red (fig. 19.). After another washing a bleaching action changed all the interior of the dark appendage, from the upper edge of the green to the end of the red rays, to a very pale buff colour: after a while a yellow brown or dark buff image appeared in its interior under the orange, yellow and green, leaving a very dark margin; and now the whole image was surrounded by an inky pink-coloured border, much wider than the visible spectrum, extending on a long neck to the dark disc already mentioned, in which the uppermost spot was seen, but the whole of the dark border had vanished next day.

I have not found much variety of colour, although it was occasionally remarkable: the juice of the thread-shaped petals of a yellow thistle in distilled water gave a bright yellow colour to white paper, on which the spectrum impressed a very long narrow image throughout the whole visible rays, varying in colour and intensity.

The darkest part lay between the lowest edge of the blue and the highest extremity of the lavender rays: that under the lavender was bright red, while the part under the violet, indigo and blue, was orange-coloured. From the blue to the end of the red was deep yellow, and below the red rays two insulated spots of the same deep yellow were formed, though somewhat blended together. On the juice of *Plumbago auriculata* the lavender and violet rays produced a pale brown image; the indigo rays had no effect, while all the rest of the image under the mean and least refrangible rays was blue and indigo; some of the juice having remained till next day, the moisture had evaporated from it, leaving a yellowish-brown sediment in the bottom of the cup, surrounded by a border of indigo, the very same colours that were separated by the solar rays and impressed upon paper the day before, showing a striking analogy between the action of the two ends of the spectrum and that of the poles of a galvanic battery. There was a green ring between the brown and the blue where the two colours were blended, and this also was visible in the greenish-yellow tint of the general ground of the paper after exposure to light. I now expected to find that paper washed with the brown sediment, dissolved in distilled water, would be impressed with the brown part of the image only, and this was the case, with the exception of some slight indication of brown at the place of the spots. There was not enough of the blue pure to enable me to obtain the indigo part of the figure alone.

The variation in the width of the images impressed by the same spectrum on different vegetable substances was remarkable; on the juice of the yellow thistle already mentioned, the image was but a mere line, nor was it much broader on the juice of Plumbago: it was wider on the juice of the dahlia, but the addition of a drop of sulphuric acid increased the width greatly, as in the images formed on the juice of beet-root, the petals of dahlia, balsam and others. Possibly the cause of this may have been the dispersion of the rays by the acid, which was particularly great in the most luminous rays of the spectrum, though in various instances, where acid was not used, the action of the spectrum seemed to extend laterally beyond its visible edges. This occurred especially when a surface of slightly browned nitrate of silver was washed with vegetable juices or other liquids. Under these circumstances the image frequently consisted of a succession of borders of various breadth and intensity surrounding a central oblong nucleus, resembling the section of a bulbous root cut longitudinally and exhibiting its coatings. For example, a slightly sunned surface of nitrate of silver, washed with the juice of the young green walnut in a strong solution of common salt became lilac, though the liquid itself was brownish; but under the spectrum an olive-brown image was formed from the upper edge of the orange rays to a considerable distance beyond the violet, where it tapered to nearly a point. After two or three washings with the liquid, the internal part was changed to a paler tint from the indigo rays to below the red. The part projecting down from the red was much narrower than the rest of the figure and ended in a curve. Then a dark and almost elliptical figure was formed within the pale part inclosing part of the paler surface, and in the centre of which a very dark oblong spot appeared ; thus from the exterior lilac ground on each side of the image to the central spot, there were five changes of intensity and tint, reckoning the central spot, but not the lilac ground ; and though several of these were mere lines, the whole figure was considerably larger than the visible spectrum (fig. 21.). Another remarkable instance occurred, both of these bands and of the breadth of the image, when paper coated with white nitrate of silver was washed with the milky juice of the fig-tree in alcohol, exposed wet to the spectrum. The first effect was a fine clear brown image, beginning with a curve at the orange, and extending far beyond the violet rays, within which an olive-green centre began to appear under the green rays, which by degrees extended to the end of the violet. The brown edges bordering the olive-green were strongly marked, and seemed to spread beyond the sides of the visible spectrum throughout the violet, indigo, blue and green, but were united by a very black round spot under the yellow, and this spot was inclosed on the under side by a brick-red cusp stretching up on each side beyond the orange rays, at the lower end of which was a circular spot of very pale yellowish-white ; the whole figure was surrounded by a broad reddish border, and after long exposure the centre of the green assumed a dark greyish hue, so that there were various tints, estimating laterally from the ground to the centre of the figure (fig. 22.).

Juice of the dark purple flower of a kind of mint in alcohol afforded another instance of several bands. The liquid gave the paper a brownish tint, on which the spectrum impressed a long dark line about the breadth of a common pin, cut off by the orange rays, but reaching to the end of the violet. On being again washed with the juice, the dark brown line gradually increased in width, taking a curved termination in the yellow, where it was broadest and tapering upwards ; the interior afterwards assumed a pale hue, leaving a dark margin ; the whole at last was surrounded by a pale border bounded by a very dark line, which were barely visible next day. Two insulated dark spots were distinctly marked below the image.

These out of many instances are sufficient to show the peculiar appearance alluded to, which it is difficult to account for, unless that at each successive washing the heat of the spectrum, by drying the parts immediately around it more rapidly than the rest of the surface, may thus produce the various borders, and extend the figure beyond its visible edges ; however, some of the other phenomena could not be so explained, and possibly may have been connected with the action of the atmospheres of the sun or earth, as you have remarked, or to a difference in the action of the rays at the edges of the sun's disc from those in its centre. I fear I may have made some mistakes, especially in the estimation of the action of the different coloured rays, the limits of which it was extremely difficult to determine in so small a spectrum as that with which I worked.

IX. *On the Use of the Barometric Thermometer for the Determination of Relative Heights. By* James R. Christie, *Esq., of the Royal Military Academy. Communicated by* S. Hunter Christie, *Esq., Sec. R.S., &c.*

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Although the observation of the temperature of boiling water has been for some time, but not extensively, employed for the determination of relative heights, yet the only means which experiment has confirmed of reducing it to a measure of the atmospheric pressure as usually estimated by the height of an equiponderate column of mercury has, till very recently, been overlooked; and it may perhaps be owing to this circumstance that the instrument for making the requisite observations remains to have fully developed in it the advantages it undoubtedly possesses, in portability and strength of construction, over the fragile and easily deranged barometer.

My attention having been called to this subject by a remark made by Professor Forbes in his interesting work on the Alps, to the effect that he had found the temperature of boiling water to decrease uniformly with the increase in height of the place of observation, and at the rate of one degree of Fahrenheit for every 550 feet of vertical ascent, I considered that it would be highly satisfactory to verify this result during an excursion over the Alps of Savoy and Piedmont which I then had in contemplation, and in the course of which I proposed to visit some localities at very considerable elevations above the sea level: and I was induced also to seek for some foundation for this very simple law. In prosecuting the latter inquiry, I soon found that, by assuming the truth of De Luc's formula for the determination of the boiling-point from the barometric pressure, at all accessible heights, a corroboration of the law in question is at once arrived at. I have since found, by reference to a paper in Vol. xv. of the Transactions of the Royal Society of Edinburgh, that Professor Forbes had himself verified his original conjecture in the same manner.

The formula alluded to, when reduced to the common English units of measure, becomes

$$b=\frac{99}{\cdot 899}\cdot \log 10\beta-60{\cdot}804 \quad \ldots\ldots\ldots \quad \text{I.}$$

where b is the variable boiling-point on Fahrenheit's scale, and β the corresponding barometric pressure in inches of mercury. From this we obtain at once

$$\log 10\beta=\frac{\cdot 899}{99}(b+60{\cdot}804)$$

and, calling β' and b' two other corresponding values of β and b, we have

$$\log\beta-\log\beta'=\frac{\cdot 899}{99}(b-b').$$

Substituting this value in Laplace's formula for the determination of H, the number of English feet in vertical height between two stations, where the barometric pressures are β and β', and the mean temperature of the air at which is t, viz.

$$H=60345\cdot 6(\log\beta-\log\beta')\{1+(t-32^\circ)\cdot 00222\},$$

we finally get

$$H=547\cdot 99(b-b')\{1+(t-32^\circ)\cdot 00222\} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad \text{II.}$$

That a very high degree of accuracy attaches to the formula I. is at once evident from the observations made, in test of it, by its author, and more especially from the one made by De Saussure on the summit of Mont Blanc with the same object. I proposed therefore, in undertaking a series of observations at elevated places, to restrict myself to the question of the fitness of the barometric thermometer, in its present form, for affording trustworthy data; making observations at stations whose heights had been previously well-determined, and at as great elevations as circumstances would admit: and, in case of feeling satisfied on this point, I considered that it would be interesting to determine the extent of accuracy to which such a series of observations would give the relative levels of successive places of observation, without reference to the simultaneous observations at any fixed station.

The instrument with which my observations were made consists of a brass cylindrical boiler, 3 inches in depth and 2·25 inches in internal diameter, supported, when in use, upon a brass tripod stand; in the upper disc of this cylinder a thermometer, graduated from 181° to 215° Fahr., is made to screw by means of a strong brass collar, one inch in diameter, surrounding the tube at the distance of two inches from the bulb, which is of a pear-shaped form, having the diameter of its largest circular section ·75 inch. The whole length of the scale is rather more than twelve inches, and each degree is ·343 inch in length, subdivided into tenths, and reading, by means of a vernier, to hundredths; the index at the zero point of the vernier by enveloping the tube prevents the intrusion of parallax. The water in the boiler is heated by means of a small spirit-lamp, which I have always found sufficient for that purpose, even in situations exposed to considerable force of wind, when protected by a shade formed by coiling up and pinning together the ends of a sheet of stiff paper. The escape of steam is at a small orifice, ·15 inch in diameter, in the upper disc of the boiler, and also through the aperture left between the tube of the thermometer and its screw collar. In using the instrument I was careful to have the water as nearly as possible of the same depth on all occasions, and to make use of the purest I could procure, which was apparently always sufficiently free from any admixture of foreign matter likely to cause appreciable error in the boiling-point.

It was necessary, before deducing any results from observations made, to determine whether the instrumental graduations could be relied on; and not having had an opportunity of comparing the instrument with any standard barometer in England, I was under the necessity of employing my Geneva observations for that purpose, comparing them with the corresponding indications of the barometer at the Geneva observatory, the height of which I estimated at seventy feet above the spot at which my observations were made. This difference of level will amount to

$$\frac{70}{548}=\cdot128^\circ\ \text{Fahr.}$$

to be added to the boiling-point as deduced from the height of the barometer. These corresponding observations were

Geneva.

Observed boiling-point.	Reduced barometer.	Calculated boiling-point.
208·820	·72129 metre.	209·357
209·115	·72345 metre.	209·500

$$\begin{array}{lrl}
\text{We have then} & 209\cdot357+\cdot128-208\cdot820= & \cdot665\ \text{error,}\\
\text{and} & 209\cdot500+\cdot128-209\cdot115= & \cdot513\ \text{error}\\
 & & \overline{2)1\cdot178}\\
 & \text{Mean error}\ \ .\ \ .\ \ .\ \ .\ \ = & -\cdot589
\end{array}$$

The non-accordance of the errors I am inclined to attribute to the latter pair of observations not being simultaneous, mine being made at 6 A.M. and the barometric indication being deduced from that recorded at 9 A.M., which is the earliest.

It was at once evident to me that the above error was not likely to afford a constant correction to be applied to all observations made at different points of the scale, because the lower point of graduation, being necessarily above the freezing-point, must have been determined by reference to a standard thermometer, and it was therefore not at all probable that it would differ from the truth by so large a quantity. An excellent opportunity of proving the truth of this conjecture offered itself at the Convent of the Great St. Bernard, where a register is kept of the variations of the barometric column. Arranging these as before, I obtain the results:—

Great St. Bernard.

Observed boiling-point.	Reduced barometer.	Calculated boiling-point.	Error.
197·640	·56538 metre.	197·709	—·069
197·680	·56630 metre.	197·787	—·107

There was a difference of level of ten or twelve feet between the two places of observation, the first having been made in the salle-à-manger of the Convent, and the other in one of the dormitories on the next floor where the barometer is fixed. The correction for this change of level is

$$-\frac{12}{548}=-\cdot022$$

to be added to the error of the first observation, which becomes then —·091; and the mean error derived from the two observations is —·099.

The instrumental error thus diminishing appears to indicate that there is a point on the scale where it becomes 0, and beyond which, as a correction, it must be applied in a negative form; and this point can readily be determined on the principle that the differences of the errors are proportional to the differences of the corresponding boiling-points; for, calling B the point on the scale at which the error vanishes, b, b', e and e' two other points and their corresponding errors, we have the equation

$$\frac{b-\mathrm{B}}{b-b'}=\frac{e\pm0}{e-e'};$$

whence

$$\mathrm{B}=b-\frac{e.(b-b')}{e-e'};$$

and, substituting in this the values above found, viz.

$$b=208^\circ{\cdot}967,\ b'=197^\circ{\cdot}649,$$

$$e=-\ {\cdot}589,\ e'=-\ {\cdot}099,$$

we find

$$\mathrm{B}=195{\cdot}363.$$

In order, by means of this result, to determine the correction to be applied as a multiplier to the number of degrees above or below B, it remains to determine the amount of error due to each degree, which, in fact, when its sign is changed, will be the required factor; calling this correction C, we have

$$\mathrm{C}=\frac{-e}{b-\mathrm{B}}=\frac{{\cdot}589}{13{\cdot}604}={\cdot}0433.$$

It may be remarked, that the principle on which the determination of this correction is founded remains unaffected by the supposition that the errors from which it is derived are partly attributable to the diameter of the bore of the thermometer increasing uniformly in descending; this I have satisfied myself by the usual means to be the case, though to a comparatively trifling amount.

The observations recorded at the Geneva Observatory and those at the Great St. Bernard afford an excellent means of applying my own to the determination of the height of my several stations, since those places present the advantage of being, the one my starting-point, and the other a position central to my series of stations. The readiest way of thus applying them appears to be, to reduce the height of the barometric column as given in millimètres to the form of the corresponding temperature of boiling water, by means of De Luc's formula above given, and then, for the determination of the difference of altitude between each station and Geneva, and the Great St. Bernard, to employ the formula

$$\mathrm{H}=\{548(b-b')\pm24\mathrm{D}\}\{1+(t-32){\cdot}00222\},$$

where D is the difference in degrees between B(=195·4) and the observed boiling-point; and the factor 24 is the product 548×·0433; the sign + being used when my own station is *lowest* and *vice versâ*, because the instrumental error is always one of defect.

Thus, taking the observations made on the Bonhomme and the corresponding ones at Geneva and the Great St. Bernard, we have,

Barom. Geneva. Boiling-point.
720·97 mm. gives 209·335

Obs^{d} boil^{g}-p^{t} 197°·700 197·700
195·4 11·635 × 548 = 6376
2·3 × 24 = 55 55
6321 × 1·059 = 6694 above Geneva Obs^{y}.
1334 Observ^{y} above sea.

Croix du Bonhomme above the sea 8028 feet.

Barom. G.S.B. Boiling-point.
563·94 mm. gives 197·587
197·700
·113 × 548 = 61·9
55
116·9 × 1·0357 = 121 below Great St. Bernard.
8170 Gt. St. Bernard above the sea.

Croix du Bonhomme above the sea 8049 feet.

The following Table shows the simultaneous observations at the two fixed stations and at the variable one, and the results derived from them by the above method.

TABLE I.

Station.	Observed boiling-point.	Temperature of the air, FAHRENHEIT.	Geneva barometer (reduced to 32° F.) in millimetres.	Geneva external thermometer *centigrade.*	Great St. Bernard barometer (reduced to 32° F.) in millimetres.	Great St. Bernard external thermometer *centigrade.*	Calculated height in feet above Geneva observatory.	Calculated depression in feet below the Great St. Bernard.	Sum of the two preceding (6836 true).	Height in feet above the sea by Geneva observation.	Height in feet above the sea by G.S.B. observatory.	Height in feet as previously determined.	Authority for the preceding column.
Les Rousses	204°·48	57°	722·01	19°·4	566·66	5°·9	2644	4024	6668	3978	4146	3919	WOERL.
Geneva	208·82	71	721·29	19·5	563·98	8·2	(−70)	6862	6792	......	1308	1334	Bib. Univ. de Génève.
Bonneville	208·715	66	722·69	21·7	564·14	6·4	90	6730	6820	1424	1440	1452	SAUSSURE.
Môle (summit)	199·855	53	723·03	19·7	565·00	4·0	5519	1300	6819	6853	6870	6221	PICTET.
St. Jeoire	208·40	62	724·54	17·9	565·73	5·3	352	6424	6776	1686	1746	1778	KELLER.
Samoens	207·94	55·5	727·61	17·0	566·91	2·5	747	6017	6764	2085	2153	2257	WOERL.
Col Dichaud	198·24	52	727·73	23·9	568·46	7·3	6695	224	6919	8029	7946		
Servoz	207·31	58	729·06	15·5	569·25	4·0	1171	5571	6742	2505	2599		
Chamounix—1	205·70	66·5	728·50	20·3	569·44	10·0	2174	4695	6869	3508	3475	3364	SAUSSURE.
Chamounix—2	205·50	50·5	723·91	17·6	568·38	5·1	2076	4663	6739	3410	3507	3425	FORBES.
Chamounix—3	205·52	68	721·40	15·4	566·11	9·2	1996	4751	6747	3330	3419	3408	WOERL.
Montanvert	200·27	62	722·57	22·1	568·19	9·6	5286	1464	6750	6620	6706	6300	FORBES.
Contamines—1	204·71	63	722·61	19·3	565·80	5·5	2544	4223	6767	3877	3947	4260	WOERL.
Contamines—2	204·72	62	722·41	15·4	564·33	6·5	2561	4305	6866	3896	3865	3259	KELLER.
Croix du Bonhomme	197·70	49	720·97	19·9	563·94	8·5	6694	131	6825	8028	8049	8026	SAUSSURE.
Chapiu—1.	202·35	54	721·67	15·5	563·55	3·4	3889	2883	6772	5223	5287	5071	SAUSSURE.
Chapiu—2.	202·655	52	724·52	17·5	563·02	1·2	3821	3069	6880	5155	5101	5006	WOERL.
Bourg St. Maurice	207·00	59	726·97	16·5	565·59	1·2	1295	5534	6829	2629	2636		
Hospice Pt. St. Bernard	199·24	50	724·47	22·9	566·64	9·0	5870	905	6775	7203	7265	7194	SAUSSURE.
Cormayeur—1.	204·75	57	723·74	16·0	565·69	4·3	2441	4336	6777	3775	3834	3997	SAUSSURE.
Cormayeur—2.	204·60	55·5	721·98	12·8	562·32	4·2	2535	4280	6815	3869	3890	4167	FORBES.
Cormayeur—3.	204·36	54	724·81	17·3	565·61	7·3	2806	3990	6796	4140	4180	4046	WOERL.
Aosta—1.	208·59	73	724·19	19·4	565·72	8·7	225	6651	6876	1561	1519	1938	SAUSSURE.
Aosta—2.	208·46	61	721·74	14·2	561·61	+ ·2	205	6581	6786	1539	1589		
Aosta—3.	208·35	68	722·23	15·9	561·26	+ 1·8	293	6611	6904	1627	1559		
Aosta—4.	208·59	57	726·08	15·3	563·75	− 2·1	293	6505	6798	1627	1665		
Aosta—5.	208·56	72	726·41	20·4	567·18	+ 6·6	361	6542	6903	1695	1628		
St. Remy	202·545	52	725·55	17·4	564·82	+ 0·6	3928	2913	6841	5262	5257	5263	SAUSSURE.
Great St. Bernard—1.	197·64	39	725·23	17·4	565·27	+ 2·7	6791	......	6791	8125	......	8170	Bib. Univ. de Génève.
Great St. Bernard—2.	197·68	38	726·42	17·1	566·67	6·5	6753	......	6753	8087	......	8038	SAUSSURE.
St. Vincent—1.	209·28	63	727·96	15·9	568·84	3·6	− 54	6785	6731	1280	1385		
St. Vincent—2.	209·64	55	730·25	20·0	569·04	2·8	− 184	6799	6615	1150	1371		
Col de Jou	202·82	56	730·25	21·0	569·99	5·8	3984	2871	6855	5318	5299		
Brussone	204·65	66·5	730·25	22·8	570·41	7·3	2904	3740	6644	4238	4430	4431	FORBES.
Col Ranzola	199·45	53	728·99	24·3	570·59	7·9	6012	843	6855	7346	7327	7136	FORBES.
Gressonay—1.	204·06	58·5	730·52	18·0	570·94	4·3	3224	3681	6905	4558	4489	4208	SAUSSURE.
Gressonay—2.	204·33	58·5	730·15	18·4	570·29	6·1	3050	3766	6816	4384	4404	4526	WOERL.
Gressonay—3.	203·92	57	730·37	16·9	568·27	2·6	3294	3752	7046	4628	4418		
Col Val Dobbia	197·44	52	730·40	19·4	568·75	2·8	7226	− 262	6964	8560	8432	7904	SAUSSURE.
La Riva—1.	205·54	61	729·94	15·8	569·74	2·5	2299	4494	6793	3633	3676	3568	SAUSSURE.
La Riva—2.	205·55	55	727·70	18·0	569·40	7·0	2200	4527	6727	3534	3643	3636	WOERL.
Varallo—1.	209·36	67	728·18	20·0	570·86	7·4	− 96	6814	6718	1238	1356		
Varallo—2.	209·26	63	727·82	20·0	570·52	6·2	− 47	6727	6680	1287	1443	1491	WOERL.
La Colma	206·72	70	728·20	27·1	571·67	13·8	1560	5263	6823	2894	2907		
Orta—1.	210·70	74	729·11	21·5	572·34	8·5	− 895	7621	6726	439	549	1108	WOERL.
Orta—2.	210·83	70	729·79	22·9	571·80	11·2	− 921	7628	6707	387	518		
Orta—3.	210·35	66	728·80	18·0	569·67	5·6	− 681	7452	6771	653	·718		
Mogadino—1.	211·04	77	727·80	19·4	568·60	5·2	−1146	7985	6839	188	185	678	SAUSSURE.
Mogadino—2.	211·20	68	724·55	18·0	566·74	6·0	−1368	8110	6742	− 34	+ 60		
Domo d'Ossola—1.	210·68	78	723·38	17·4	565·64	5·9	−1104	7933	6829	230	237	1004	SAUSSURE.
Domo d'Ossola—2.	210·44	66	723·27	16·0	563·89	4·5	− 943	7751	6808	391	419		
Simplon Village	203·28	57	724·03	17·0	564·12	7·4	3440	3441	6881	4729	4774	4792	WOERL.
Simplon Hospice	201·07	48	724·00	19·0	564·13	5·3	4753	2084	6837	6087	6086	6580	SAUSSURE.
Brieg—1.	208·69	61	726·01	11·4	564·45	+ 1·6	229	6606	6835	1563	1564	2328	SAUSSURE.
Brieg—2.	208·35	56	729·28	15·0	566·00	− 1·3	552	6194	6746	1886	1976	2183	WOERL.
Leukerbad—1.	204·38	47·5	733·42	14·6	570·43	− 1·2	3104	3673	6777	4438	4497	4699	WOERL.
Leukerbad—2.	204·545	45	734·75	13·7	571·54	+ 2·0	3025	3749	6774	4359	4421		
S. Crest of the Gemmi	199·235	41	734·44	19·7	572·06	4·7	6235	620	6855	7569	7550	7626	WOERL.
Kandersteg—1.	206·34	55·5	733·06	16·3	572·45	3·0	1922	4816	6738	3256	3354	3493	WOERL.
Kandersteg—2.	206·17	48	732·09	15·8	571·74	9·3	1972	4765	6737	3306	3405		
Lauterbrunnen—1.	208·28	55	728·81	16·6	570·66	8·8	585	6112	6697	1918	1958		
Lauterbrunnen—2.	208·37	49	727·68	17·6	569·18	10·3	484	6215	6699	1818	1955		
Bern	209·26	72	726·97	22·4	569·91	11·0	− 82	6883	6801	1252	1287	1661	WOERL.

The discrepancies in many of the above results as compared with the column of previously determined heights are considerable, but it is to be observed that in most cases where the height of the station may be considered as particularly well-established, the observed height accords with it in a very remarkable manner. This is particularly the case at Geneva (where the height is of course deduced only from that of the Great St. Bernard), at Bonneville, at Chamounix (taking a mean of the six observations, which gives 3442), at the Croix du Bonhomme[*], at St. Remy, at the Great St. Bernard and at Brussone: the chief exceptions being at the Môle[†], the Montanvert, the Col di Val Dobbia, Orta, Mogadino, Domo d'Ossola, the Simplon Hospice and Brieg, the great differences at which places are to me quite unaccountable, unless on the supposition, in the case of the five last-named, that their distances from the fixed stations were too great to allow of trustworthy results being obtained from single observations. In confirmation of this view, it will be seen presently that these observations give far more satisfactory results when employed without any reference to the simultaneous observations at Geneva and the Great St. Bernard; and also in the above Table we may notice that, after crossing the Bonhomme, in those cases where the heights determined from the two fixed stations differ from one another to any considerable amount, that obtained by reference to the Great St. Bernard generally approximates more nearly to the height as previously determined than the other, obtained by a comparison with the more distant station.

The numbers in the tenth column which are the sums of the two values, the height above Geneva and the depression below the Great St. Bernard, as determined by observation, should, supposing both theory and observations to be perfect, give the constant value 6836, which is the difference of height of those two stations; but this difference will vary when determined by means of each pair of barometric observations, the standard value 6836 being the mean of a very considerable number. Now it is very evident that were it not for that term in the formula which involves the correction for the expansion of the air, the sum of the above values would give the difference of altitude, however erroneous the intermediate observation might be: for calling b', b'' and b''' the three boiling-points, we should have

$$548(b'-b'')-24\mathrm{D}+548(b''-b''')+24\mathrm{D}=548(b'-b''').$$

The observation, therefore, of the external temperature at the intermediate station becomes the means of rendering the accordance of the sums of the component altitudes with the whole height between Geneva and the Great St. Bernard, as determined in each case, a test of the correctness of the observation of the boiling temperature. We may in fact, by equating the formula for the whole height with the sum of those expressing the two component heights, arrive at an expression for the intermediate boiling-point in terms of the atmospheric temperatures at the three stations and the upper and lower boiling-points; such an expression is

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[*] All who have traversed the Pass of the Bonhomme are aware that in crossing to the south, upon Chapiu, the tract rises considerably after passing what ought to be and, I believe, *is* considered the "*Col*," viz. the point from which a view of the mountains of the Tarentaise is first obtained; this point is marked by a cross, larger than usual on most passes, and than any of the numerous others on this pass. This cross I believe to be the "*Croix du Bonhomme*" of De Saussure, and it was at its base the observation above referred to was made.

[†] See note, p. 131.

$$b''=\frac{23}{24}\cdot\left\{\frac{t-\mathrm{T}'}{\mathrm{T}-\mathrm{T}'}\cdot b'+\frac{\mathrm{T}-t}{\mathrm{T}-\mathrm{T}'}\,b'''+8\cdot4\right\}$$

where T, t and T′ are the temperatures at the stations where the boiling-points are respectively b', b'' and b'''; but this, when put in the form

$$b''=\frac{23}{24}\cdot\left\{\frac{t.(b'-b''')+\mathrm{T}b'''-\mathrm{T}'b'}{\mathrm{T}-\mathrm{T}'}+8\cdot4\right\},$$

shows us that an error in the value of t, of trifling moment where that value is to be employed in the determination of the difference of level, will cause an error in the resulting boiling temperature of very serious amount when used for the same purpose. Though this test cannot therefore be made use of in its full rigour, it will be highly satisfactory if an accordance can be shown between the results above referred to: the following, Table II., exhibits a comparison of these values. The numbers in the second column are the differences of the boiling temperatures, in degrees of FAHRENHEIT, deduced from the barometric observations at Geneva and the Great St. Bernard, which were simultaneous with those of my own made at the places named in the first column.

TABLE II.

Station.	Difference of boiling-points derived from the observations at Geneva and the Great St. Bernard.	Value of $(t-32°)$ in formula II.	Derived difference of height.	Difference of height from Table I.	Station.	Difference of boiling-points derived from the observations at Geneva and the Great St. Bernard.	Value of $(t-32°)$ in formula II.	Derived difference of height.	Difference of height from Table I.
Les Rousses	11°·583	22°·8	6669	6668	Col de Jou	11°·860	24°·1	6847	6855
Geneva				6792	Brussone	11·372	27·0	6605	6644
Bonneville	11·856	25·3	6862	6820	Col Ranzola	11·716	29·0	6833	6855
Môle	11·794	21·4	6768	6810	Gressonay—1.	11·789	20·0	6719	6905
St. Jeoire	11·832	20·9	6784	6776	Gressonay—2.	11·818	22·0	6763	6816
Samoens	11·936	17·6	6796	6764	Gressonay—3.	12·003	17·5	6833	7046
Col Dichaud	11·813	28·1	6877	6919	Col di Val Dobbia	11·964	20·0	6847	6964
Servoz	11·834	12·6	6666	6742	La Riva—1.	11·851	16·5	6735	6793
Chamounix—1.	11·781	27·3	6846	6869	La Riva—2.	11·729	22·5	6749	6727
Chamounix—2.	11·568	20·5	6627	6739	Varallo—1.	11·640	24·7	6728	6718
Chamounix—3.	11·593	22·2	6664	6747	Varallo—2.	11·646	23·6	6716	6680
Montanvert	11·491	28·6	6696	6750	La Colma	11·574	26·8	6860	6823
Contamines—1.	11·699	22·3	6728	6767	Orta—1.	11·578	27·0	6725	6726
Contamines—2.	11·811	19·7	6755	6866	Orta—2.	11·661	25·7	6758	6707
Croix du Bonhomme	11·748	25·6	6803	6825	Orta—3.	11·782	21·3	6761	6771
Chapiu—1.	11·828	17·0	6726	6772	Mogadino—1.	11·805	22·1	6786	6839
Chapiu—2.	12·061	16·9	6857	6880	Mogadino—2.	11·748	21·6	6746	6742
Bourg St. Maurice	12·005	16·0	6811	6829	Domo d'Ossola—1.	11·764	20·9	6746	6829
Hospice Pt. St. Bernard	11·642	28·7	6786	6775	Domo d'Ossola—2.	11·865	18·5	6762	6808
Cormayeur—1.	11·748	25·6	6803	6777	Simplon Village	11·936	22·0	6859	6881
Cormayeur—2.	11·953	15·4	6775	6815	Simplon Hospice	11·933	20·9	6842	6837
Cormayeur—3.	11·861	27·1	6852	6796	Brieg—1.	12·038	11·7	6768	6835
Aosta—1.	11·809	25·3	6835	6876	Brieg—2.	12·121	12·4	6826	6746
Aosta—2.	11·997	13·0	6785	6786	Leukerbad—1.	12·020	12·1	6763	6777
Aosta—3.	12·060	15·9	6842	6904	Leukerbad—2.	12·014	14·2	6790	6774
Aosta—4.	12·102	13·2	6806	6798	South Crest of the Gemmi	11·950	22·0	6868	6855
Aosta—5.	11·895	24·3	6835	6903	Kandersteg—1.	11·828	17·4	6731	6738
St. Remy	11·976	16·2	6798	6841	Kandersteg—2.	11·823	22·6	6804	6737
Great St. Bernard—1.	11·911	18·1	6790	6791	Lauterbrunnen—1.	11·700	22·9	6737	6697
Great St. Bernard—2.	11·873	21·3	6816	6753	Lauterbrunnen—2.	11·749	25·1	6797	6699
St. Vincent—1.	11·795	16·5	6715	6731	Bern	11·641	30·1	6805	6801
St. Vincent—2.	11·930	20·5	6835	6615					

It is to be observed, that the differences of height determined by the two methods do not differ from one another in any single case by so large a quantity as do the greatest and least difference of level in the fourth column, determined from the barometric observations at the two places; while in many the accordance is almost perfect. One of the most satisfactory results in this respect is, however, that derived from the observation No. 2. at Mogadino, which appears from Table I. to be one of those least likely to be correct, since it places the surface of the Lago Maggiore much below its possible level. This alone sufficiently shows that the accordance above remarked can only be taken as a general indication of the accuracy of the instrument.

Having thus shown that the instrument is perfectly capable of furnishing correct data for the determination of difference of level, though apparently its indications cannot in all cases be relied on, it becomes further interesting to inquire how far it may be depended on when made use of without reference to corresponding observations at any fixed station. It is obvious that the accuracy of a series of heights thus obtained must, to a certain extent, be vitiated by the diurnal changes in the atmospheric pressure, but it will be seen that this source of error does not operate to the extent that might, *à priori*, be supposed probable, and that, whether from a fortuitous balancing of errors, or from some other cause, the discrepancies in those cases where the previously determined height is probably most near the truth, are less considerable than might be expected. In order thus to obtain the results given in the following Table III., it became necessary again to modify the standard formula on account of the instrumental error. By multiplying the correction, C=·0433, by 548 we obtain it in the form of a difference of altitude for each degree of observed difference of boiling temperature at two successive places of observation, to be added to the factor 548 to form the constant multiplier for this particular instrument. We thus obtain

$$548 \times 1{\cdot}0433 = 571{\cdot}72,$$

or, with sufficient accuracy, 572.

The working formula then becomes

$$H = 572(b-b').\{1+(t-32^\circ){\cdot}00222\}.$$

In the following Table, in which the results have been calculated with this formula, the differences of level are determined from station to station in the order in which the observations were made, and, in case of two or more observations having been made at the same station, those most approximate in time have been employed. Taking the station at Geneva as a starting-point, and assuming its level, derived from that of the surface of the lake given in the Bibliothèque Universelle de Génève, to be 1264 English feet above the sea level, the calculated differences have been added to this in succession, and the altitudes by observation obtained.

TABLE III.

Station.	Time of observation, 1844.	External temperature of the air.	Observed boiling-point.	Dif. of altitude in ft.	Altitude in feet.	Altitude as previously determined.	Authority for the altitudes in the preceding column.
	h m						
Les Rousses (Jura)	June 25. 5 30 A.M.	57°	204°·48	2767	4031	3919	WOERL.
Geneva—1.	25. 0 30 P.M.	71	208·82	2767	....	1264	Bib. Univ. de Génève.
Geneva—2.	26. 6 15 A.M.	62	209·115				
Bonneville	26. 11 45 A.M.	66	208·715	247	1511	1452	SAUSSURE.
Môle	26. 6 15 P.M.	53	199·855	5388	6899	6094 6221	SAUSSURE. PICTET.
St. Jeoire	27. 8 0 A.M.	62	208·40	5166	1733	1893	DE LUC.
Samoens	28. 5 30 A.M.	55·5	207·94	278	2011	2270	DE LUC.
Col Dichaud (Buet)	28. 3 45 P.M.	52	198·24	5816	7827		
Servoz	29. 7 30 A.M.	58	207·31	5453	2374		
Chamounix—1.	29. 1 45 P.M.	66·5	205·70	983	3357	3364	SAUSSURE.
Chamounix—2.	30. 4 30 A.M.	50·5	205·50	....	....	3425	FORBES.
Montanvert	30. 0 15 P.M.	62	200·27	3152	6509	6101 6300	SAUSSURE. FORBES.
Chamounix—3.	30. 4 20 P.M.	68	205·52	3223	3286	3356	PICTET.
Contamines	July 1. 7 15 P.M.	63	204·71	500	3786	3328	KELLER.
	2. 9 15 A.M.	62	204·72	....	....	4260	WOERL.
Croix du Bonhomme	2. 3 30 P.M.	49	197·70	4269	8055	8026	SAUSSURE.
Chapiu—1.	2. 7 30 P.M.	54	202·35	2775	5280	5071	SAUSSURE.
Chapiu—2.	3. 9 20 A.M.	52	202·655	....	....	4974	PICTET.
Bourg St. Maurice	3. 8 0 P.M.	59	207·00	2566	2714		
Petit St. Bernard	4. 11 45 A.M.	50	199·24	4660	7374	7194	SAUSSURE.
Cormayeur—1.	4. 9 30 P.M.	57	204·75	3302	4072	3997	SAUSSURE.
Cormayeur—2.	7. 7 0 A.M.	54	204·36	....	....	4167	FORBES.
Aosta—1.	7. 1 45 P.M.	73	208·59	2589	1483	1938	SAUSSURE.
Aosta—2.	9. 5 30 A.M.	57	208·59	....	....	1980	WOERL.
St. Remy	9. 11 45 A.M.	52	202·545	3631	5114	5263	SAUSSURE.
Grand St. Bernard—1.	9. 3 30 P.M.	39	197·640	2891	8003	8038	SAUSSURE.
Grand St. Bernard—2.	10. 6 30 A.M.	38	197·680	....	....	8170	Bib. Univ. de Génève.
Aosta—3.	10. 0 30 P.M.	72	208·560	6541	1462		
St. Vincent—1.	10. 9 0 P.M.	63	209·280	444	1018		
St. Vincent—2.	11. 5 30 A.M.	55	209·64				
Col de Jou	11. 10 30 A.M.	56	202·82	4148	5166		
Brussone	11. 0 0 noon.	66·5	204·65	1109	4057	4431	FORBES.
Col de Ranzola	11. 5 30 P.M.	53	199·45	3157	7214	7136	FORBES.
Gressonay—1.	11. 7 45 P.M.	58·5	204·06	2776	4438	4208	SAUSSURE.
Gressonay—2.	13. 8 15 A.M.	57	203·92	....	....	4526	WOERL.
Col di Val Dobbia	13. 1 0 P.M.	52	197·44	3892	8330	7904	SAUSSURE.
La Riva—1.	13. 7 30 P.M.	61	205·54	4885	3445	3568	SAUSSURE.
La Riva—2.	14. 6 0 A.M.	55	205·55	....	....	3712	WOERL.
Varallo—1.	14. 10 0 P.M.	67	209·36	2319	1126	1491	WOERL.
Varallo—2.	15. 6 45 A.M.	63	209·26				
La Colma	15. 2 15 P.M.	70	206·72	1566	2692		
Orta—1.	15. 6 45 P.M.	74	209·70	1856	836	1108	WOERL.
Orta—2.	17. 4 30 A.M.	66	210·35				
Mogadino—1.	17. 6 30 P.M.	77	211·04	430	406	678	SAUSSURE.
Mogadino—2.	18. 6 0 A.M.	68	211·20				
Domo d'Ossola—1.	18. 7 0 P.M.	78	210·68	324	735	1004	SAUSSURE.
Domo d'Ossola—2.	19. 4 30 A.M.	66	210·44				
Simplon (Village)	19. 0 30 P.M.	57	203·28	4368	5098	4792	WOERL.
Simplon Hospice	19. 4 50 P.M.	48	201·07	1323	6421	6580	SAUSSURE.
Brieg—1.	19. 10 30 P.M.	61	208·69	4581	1840	2328	SAUSSURE.
Brieg—2.	20. 7 15 A.M.	56	208·35	....	....	2183	WOERL.
Leukerbad—1.	20. 8 0 P.M.	47·5	204·38	2371	4211	4697	WOERL.
Leukerbad—2.	21. 7 0 A.M.	45	204·545				
Gemmi (châlet on south crest)	21. 0 30 P.M.	41	199·235	3112	7323	7626	WOERL.
Kandersteg—1.	21. 6 30 P.M.	55·5	206·34	4208	3115	3493	WOERL.
Kandersteg—2.	22. 6 45 A.M.	48	206·17				
Lauterbrunnen—1.	22. 9 0 P.M.	55	208·28	1251	1864		
Lauterbrunnen—2.	23. 6 45 A.M.	49	208·37				
Bern	24. 10 20 A.M.	72	209·26	536	1328	1661	WOERL.

Though the discrepancies in these results, when compared with the previously determined altitudes, appear very considerable, they are probably in most cases not more so than would have resulted from the employment of the usual form of barometer. I am led to this conclusion from the inspection of De Luc's series of barometric measurements, wherein the determinations of the height of the same station at different times frequently differ from one another 250 feet, and, in one case, as much as 360 feet. The greatest error in the above table, viz. that at Aosta*, 400 feet, certainly exceeds either of these, but there is, I think, good reason to suppose that the observed height at Aosta is not so erroneous as the comparison with De Saussure's result makes it appear to be, when we remark that the height of the Great St. Bernard determined from it is one of the most accurate of the series, and also that the observations made *the next day* at the Great St. Bernard and at Aosta give the same difference of level, within twenty feet.

The only other instance in which I was enabled to repeat an observation after the ascent of any considerable height occurred at Chamounix, and in it a tolerably close accordance in the observations before and after the ascent of the Montanvert is also to be remarked, though the height derived from the intermediate observation differs very considerably even from that given by Professor Forbes, which is however equally in excess above that by De Saussure.

Since the calculation of the above results I have had an opportunity of comparing the instrument with a standard barometer, and have been surprised to find the instrumental correction, under the pressure 30 inches, very different from that obtained above from the Geneva observations. I cannot assign any reason for supposing an error in making these observations; indeed, every consideration induces me to believe that no such error could have occurred, but at the same time I find it very difficult to account for this change in the correction, unless it be partly attributable to a difference in construction of the two barometers and partly to a difference in the degree of purity of the water, or to a change in the instrument itself; all of which suppositions are highly improbable. To whichever of the above causes this remarkable change is referred, I do not think it should be considered as vitiating the results derived from the recorded observations, since they have been connected with those made with the barometers by means of which the correction made use of has been determined; and moreover the time elapsed between the first and last recorded observations was only one month, and the sources from which the water was derived were in all cases so far similar as apparently to ensure its chemical identity with respect to boiling temperature.

The utility of an instrument to be applied to purposes which involve the necessity of its removal from place to place under difficult circumstances, is not *exclusively* to be measured by the degree of delicacy or even of accuracy of its indications; since however perfect it may be theoretically, when stationary, it can never be of practical benefit unless it be of such a construction as to bear the concussions and shaking it must be necessarily exposed to when conveyed in the manner in which it can alone arrive at the point where its agency is required. This construction has been attained in the instruments by means of which are determined the two principal coordinates of geographical position, under all circumstances involving difficulty of access to the place of observation, while the third, *height above the sea level*, has had almost exclusively applied to its determination an instrument more liable than almost any other to suffer during removal, and, from its very nature, incapable of any great improvement in this respect. With regard to the instrument under consideration, I can, in reference to the above points, speak most positively; not only were the concussions which it constantly suffered very considerable, but on two or three occasions it escaped uninjured by blows which must have shivered any common barometer, however externally protected; and it has only at length been destroyed through having been inadvertently left boiling;—the water having evaporated, the increase of temperature of the empty boiler proved too great for the capacity of the tube of the thermometer, and the bulb burst.

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* The circumstances of danger under which the observation on the Môle was made, make me think that an erroneous reading is not unlikely to have occurred there, and I accordingly exclude it from consideration in these remarks.

Since writing the above my attention has been directed to the researches of Holtzmann and Magnus, given in Vol. iv. Part 14. of the "Scientific Memoirs," and I have applied the formula for the expansive force of steam deduced by the former, to the determination of an expression for the difference of level in terms of the difference of boiling temperature. Reduced to English measures, Holtzmann's result gives

$$b-32^\circ=425{\cdot}2\times\frac{\log\beta+{\cdot}74883}{6{\cdot}73157-\log\beta}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{III.}$$

b and β being the same as in (I.).

Applying this as before, in the case of De Luc's, I obtain

$$\mathrm{H}=\frac{191939000}{(393{\cdot}2+b)(393{\cdot}2+b')}\cdot(b-b')\{1+(t-32^\circ){\cdot}00222\} \quad . \quad . \quad . \quad \text{IV.}$$

The results derived from (III.), within the limits of my observations, differ but little from those obtained from (I.), but have a tendency to diminish the boiling temperature more rapidly as the pressure decreases, as the following results sufficiently show:—

Pressure.	Temperature. De Luc.	 Holtzmann.	Diff.
721·74 mm.	209·386	209·425	+·039
561·61 mm.	197·389	197·237	—·152

Even were this last difference greater, we must still rely upon De Luc's until it can be shown that the results obtained with (III.) are more nearly in accordance with observations made under natural atmospheric pressures than those derived from (I.) have been found to be.

The practical disadvantages of (IV.) are evident.

X. *Investigation of an Extensive Class of Partial Differential Equations of the Second Order, in which the Equation of* LAPLACE'S *Functions is included.*

By G. W. HEARN, *Esq., of the Royal Military College, Sandhurst. Communicated by Sir* JOHN F. W. HERSCHEL, *Bart., F.R.S., &c.*

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Theorem. IF u be a function of x and y satisfying the equation

$$\frac{d^2u}{dxdy}+\alpha_n e^{\phi}u=0,$$

where

$$\frac{d^2\phi}{dxdy}+ce^{\phi}=0,$$

then the solution will be

$$u=\mathrm{D}^{-n}v_n$$

where

$$\mathrm{D}=e^{-\phi}\frac{d}{dy},$$

where

$$v_n=\int e^{-\frac{\beta_n}{\Delta\beta_n}\phi}\chi y dy+\psi x,$$

χy and ψx arbitrary functions of y and x,

and

$$\beta_n=\frac{\Delta\alpha_{n-1}\,.\,\Delta\alpha_{n-2}\,.\,.\,.\,.\,.}{(\Delta\alpha_{n-1}-c)(\Delta\alpha_{n-2}-c)\,.\,.\,.\,.\,.};$$

where

$$\Delta\alpha_r=\alpha_{r+1}-\alpha_r,$$

and α_n is a function of n vanishing for $n=0$ and for $n=-1$.

I will proceed to demonstrate this curious theorem as briefly as possible.

According to the notation, we may write the given equation

$$\mathrm{D}\frac{du}{dx}+\alpha_n u=0.$$

Then if

$$v_n=\mathrm{D}^n u$$

we have

$$v_{n+1}=\mathrm{D}^{n+1}u=\mathrm{D}v_n.$$

Suppose that

$$\mathrm{D}\frac{dv_n}{dx}+\beta_n z\mathrm{D}v_n=\mathrm{D}^n\left\{\mathrm{D}\frac{du}{dx}+\alpha_n u\right\}. \quad . \quad . \quad . \quad . \quad . \quad (\alpha.)$$

where z is a function of x and y to be determined, also β_n a function of u.

Writing $n+1$ for n in equation $(\alpha.)$, we ought to have

$$\mathrm{D}\frac{dv_{n+1}}{dx}+\beta_{n+1}z\mathrm{D}v_{n+1}=\mathrm{D}^{n+1}\left\{\mathrm{D}\frac{du}{dx}+\alpha_{n+1}u\right\}. \quad . \quad . \quad . \quad . \quad (\beta.)$$

This circumstance will serve to determine z and β_n as follows: we have identically

$$\mathrm{D}^{n+1}\left\{\mathrm{D}\frac{du}{dx}+\alpha_{n+1}u\right\}=\mathrm{D}^{n+1}\left\{\mathrm{D}\frac{du}{dx}+\alpha_n u\right\}+\Delta\alpha_n\mathrm{D}^{n+1}u$$

$$=\mathrm{D}^2\frac{dv_u}{dx}+\beta_n\mathrm{D}\left\{z\mathrm{D}v_n\right\}+\Delta\alpha_n\,.\,\mathrm{D}v_n \text{ by } (\alpha)$$

$$=\mathrm{D}^2\frac{dv_n}{dx}+\beta_n\mathrm{D}\left\{zv_{n+1}\right\}+\Delta\alpha_n\,.\,v_{n+1}.$$

But $$\frac{dv_{n+1}}{dx}=\frac{d}{dx}\mathrm{D}v_n=\frac{d}{dx}\left(e^{-\phi}\frac{dv_n}{dy}\right)$$

$$=-\frac{d\phi}{dx}e^{-\phi}\frac{dv_n}{dy}+e^{-\phi}\frac{d}{dy}\cdot\frac{dv_n}{dx}$$

$$=-\frac{d\phi}{dx}\mathrm{D}v_n+\mathrm{D}\frac{dv_n}{dx};$$

$$\therefore\qquad \mathrm{D}^2\frac{dv_n}{dx}=\mathrm{D}\left\{\frac{dv_{n+1}}{dx}+\frac{d\phi}{dx}v_{n+1}\right\}.$$

Hence $$\mathrm{D}\frac{dv_{n+1}}{dx}+\mathrm{D}\left(\frac{d\phi}{dx}v_{n+1}\right)+\beta_n\mathrm{D}(zv_{n+1})+\Delta\alpha_n v_{n+1}$$

ought to be identical with $\mathrm{D}\frac{dv_{n+1}}{dx}+\beta_{n+1}z\mathrm{D}v_{n+1}$, and hence the conditions

$$\frac{d\phi}{dx}+\beta_n z=\beta_{n+1}z$$

$$\mathrm{D}\left\{\frac{d\phi}{dx}+\beta_n z\right\}=-\Delta\alpha_n.$$

Eliminating z, we have

$$\mathrm{D}\frac{d\phi}{dx}=-\frac{\Delta\alpha_n\Delta\beta_n}{\beta_{n+1}}=-c,$$

or $$\frac{d^2\phi}{dxdy}+ce^{\phi}=0,$$

and $$c\beta_{n+1}=\Delta\alpha_n\{\beta_{n+1}-\beta_n\},$$

or $$\beta_{n+1}=\frac{\Delta\alpha_n}{\Delta\alpha_n-c}\cdot\beta_n;$$

$$\therefore\qquad \beta_n=\frac{\Delta\alpha_{n-1}\,.\,\Delta\alpha_{n-2}\,\ldots\ldots}{(\Delta\alpha_{n-1}-c)(\Delta\alpha_{n-2}-c)\,\ldots\ldots}:$$

by these determinations we establish the formula (β.) as a consequence of (α.), and therefore if the formula (α.) be true for any value of n, it will be (subject to the above conditions) true for the next superior value.

Now, when $n=0$, $v_0=\mathrm{D}^0u=u$, and provided α_0 and α_{-1} are each $=0$, α_0 and $\Delta\alpha_{-1}$ will be each 0, and $\therefore$ α_0 and β_0 each $=0$, and the equation (α.) reduces to $\mathrm{D}\frac{dv_0}{dx}$

$=\mathrm{D}\frac{du}{dx}$, and is therefore true for $u=0$. Under these restrictions it will therefore be true for any positive integral value of n. Now the symbol D represents $e^{-\phi}\frac{d}{dy}$, and therefore if $\mathrm{U}=0$, $\mathrm{D}^n\mathrm{U}=0$, so that we have

$$\mathrm{D}\frac{dv_n}{dx}+\beta_n z \mathrm{D}v_n=0,$$

or

$$e^{-\phi}\frac{d^2v_n}{dxdy}+\frac{\beta_n}{\Delta\beta_n}\cdot\frac{d\phi}{dx}\cdot e^{-\phi}\frac{dv_n}{dy}=0,$$

or

$$\frac{\frac{d}{dx}\cdot\frac{dv_n}{dy}}{\frac{dv_n}{dy}}=-\frac{\beta_n}{\Delta\beta_n}\cdot\frac{d\phi}{dx};$$

$\therefore$ integrating with respect to x,

$$\frac{dv_n}{dy}=e^{-\frac{\beta_n}{\Delta\beta_n}\phi}\chi y$$

$$v_n=\int e^{-\frac{\beta_n}{\Delta\beta_n}\phi}\chi y dy+\psi x,$$

and

$$u=\mathrm{D}^{-n}v_n=\int e^{\phi}\int e^{\phi}\ldots\ldots v_n dy dy\ldots.$$

the integral sign repeated n times. The theorem is therefore demonstrated.

It may be easily shown that the equation of LAPLACE'S coefficients is included in the class here considered.

The equation of LAPLACE by a proper choice of independent variables assumes the form

$$\frac{d^2u}{dxdy}+\frac{n\,.\,n+1}{4\cos^2\frac{y-x}{2}}\cdot u=0.$$

Hence with reference to the preceding investigation,

$$\mathrm{D}=\cos^2\frac{y-x}{2}\cdot\frac{d}{dy}\text{ and }\alpha_n=\frac{n\,.\,\overline{n+1}}{4}.$$

Hence $\qquad e^{-\phi}=\cos^2\frac{y-x}{2};$

$$\therefore\qquad \frac{d\phi}{dx}=-\tan\frac{y-x}{2}$$

$$\frac{d^2\phi}{dxdy}+\frac{1}{2}e^{\phi}=0.$$

Hence $\qquad c=\frac{1}{2}$. Also $\Delta\alpha_n=\frac{n+1}{2}$; $\quad\Delta\alpha_n-c=\frac{n}{2}$;

$$\therefore\qquad \beta_n=n\text{ and }\Delta\beta_n=1.$$

Inserting these values in the final formula, we have

$$v_n=\int \cos^{2n}\frac{y-x}{2}\,\chi y dy+\psi x,$$

and
$$u=\int \cos^{-2}\frac{y-x}{2}\int \cos^{-2}\frac{y-x}{2}\ldots . v_n dy dy \ldots . n \text{ times},$$

which agrees with Mr. HARGREAVE's solution.

XI. *On Spontaneous Nitrification.* *By* C. F. SCHOENBEIN, *Professor of Chemistry in the University of Bâle.* *Communicated by* MICHAEL FARADAY, *Esq., F.R.S., &c.*

Received November 6, 1845,—Read February 12, 1846.

A FACT not yet well understood is the spontaneous formation of nitric acid, or rather nitrates which takes place when azotic organic matters putrify in contact with strong bases and atmospheric air. Some chemists hold the opinion that under the circumstances mentioned, nitric acid is formed out of the nitrogen of the organic substances and atmospheric oxygen, both elements being determined to unite with one another by what is called the predisposing affinity of the bases for nitric acid.

Others maintain that the said acid originates entirely from the oxygen and nitrogen of the atmosphere, and suppose that these elements are by a sort of capillary action brought into such a condensed state as to combine into nitric acid, under the additional influence of the predisposing affinity of the bases for that acid.

According to the notions prevailing at present nitric acid comes from ammonia, which is supposed to be acted upon by the oxygen of the air, *i. e.* dehydrogenized, and its nitrogen united to oxygen. The only thing sure is, that we know very little about spontaneous nitrification.

Considering the theoretical interest connected with the obscure phenomenon in question, it must appear very desirable that novel facts should be ascertained calculated to throw light upon, and lead to the true insight into, the cause of spontaneous nitrification. The observations I am about to state will perhaps contribute a little to obtain that end.

Some years ago I ascertained the fact, that a solution of potash, sufficiently long treated with air ozonized (by the means of phosphorus), yields a liquid which, being over-saturated with sulphuric acid and heated, causes a brownish coloration round a crystal of sulphate of iron, and has the power of destroying indigo*. From that fact I inferred at the time that the reactions indicated are due to the presence of a nitrate.

Some time after I found out that the acid liquid called phosphatic acid, produced during the action of phosphorus upon moist atmospheric air, enjoys likewise the property of destroying indigo. If that acid is perceptibly coloured by a solution of indigo and left to itself, after a few hours it will have become colourless, or if the same acid be heated, its colour will be discharged within a few minutes.

Phosphatic acid, some iodide of potassium being dissolved in it, assumes a yellowish brown colour, and the same acid being neutralized by hydrate of lime, yields in small quantities a salt exhibiting all the properties of nitrate of lime. The latter being treated, for instance, with carbonate of ammonia, produces a salt which, when mixed with some strong sulphuric acid and brucine, strikes a blood-red colour, disengages fumes of hyponitric acid, &c. From these facts it appears that nitric acid is present in the phosphatic acid, the former being produced during the oxidation which phosphorus undergoes in moist atmospheric air.

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* See Les Archives de l'Electricité, No. 15, p. 417.

I have further ascertained that hydrate of lime, being suspended in water and sufficiently long treated with ozonized air, produces a salt exhibiting the properties of a nitrate.

M. Fellenberg has published* results which lead also to the conclusion, that either nitrites or nitrates are formed in treating hydrate of lime with ozonized atmospheric air, and the same chemist has made observations with the phosphatic acid coinciding with the results I have obtained from my own experiments. The philosopher of Lausanne is rather inclined to identify ozone with hyponitric acid. I think, however, that such an opinion cannot be upheld, and is contrary to facts, of which I gave an account in Poggendorff's Annals some time ago. According to my experiments, ozone destroys instantaneously hyponitric acid, hydrate of nitric acid being formed. Phosphorus does not shine in atmospheric air containing the smallest quantity of hyponitric acid, whilst phosphorus exhibits a very lively disengagement of light when placed in atmospheric air, being ever so strongly charged with ozone. Blue litmus paper being suspended in air of the latter description is not in the least reddened, but simply and rapidly bleached; whilst the same paper placed in atmospheric air, which is only slightly charged with hyponitric acid, assumes a perceptibly red colour. Ozonized air being charged with vapour of ammonia or carbonate of ammonia so strongly as to bring back instantly the blue colour of reddened litmus paper, enjoys the property of decomposing iodide of potassium (*i. e.* colouring blue the parts of starch mixed with that iodide), transforming the yellow prussiate into the red salt, colouring blue the resin of guaiacum, destroying all organic colouring matters, changing sulphuret of lead into a sulphate, &c.: the facts stated are sufficient to prove satisfactorily that ozone is not identical with hyponitric acids. I have, however, some other facts to mention which will demonstrate in the most direct manner, that ozone has nothing to do with the acid mentioned.

Ozone is abundantly produced (by means of phosphorus) in moist mixture of perfectly pure oxygen and hydrogen, or oxygen and carbonic acid. Ozone is generated by electrical sparks out of the purest oxygen obtainable, provided that principle contain some moisture. Ozone makes its appearance round the positive electrode, if a current passes through acidulated water containing no trace of nitrogen or any azotic compound. We are therefore allowed to consider it as a settled matter, that ozone is different both from nitrous and hyponitric acids.

* See Les Archives de l'Electricité, No. 17, p. 24–34.

Now, if a nitrate happens to be formed in treating, for instance, hydrate of lime with ozonized atmospheric air, it seems to follow that the nitric acid formed under those circumstances, owes, in some way or other, its origin to ozone, pure atmospheric air being unable to produce a nitrate with the hydrate named. But in what manner does ozone contribute to the formation of that acid? My experiments have shown that ozone is a very powerful oxidizing agent, so much so, that even iodine and silver are at the common temperature transformed into iodic acid and peroxide of silver. If it be a fact that the chemical powers of the oxygen contained in ozone are so much exalted as to enable that oxygen to unite with substances so little oxidable as iodine and silver are, it would not appear in my eyes very surprising if that same oxygen should happen to combine, under certain circumstances, with nitrogen to form what is called nitric acids.

According to my opinion (see my little work on the Slow and Rapid Combustion of Bodies) there does not exist a compound of nitrogen $=NO_5$. I consider what chemists call the first hydrate of nitric acid as NO_4+HO_2, and the normal nitrates as NO_4+RO_2. Nitrate of lime is therefore to me NO_4+CaO_2. Agreeable to that view, I am inclined to account for the nitrification above mentioned in the following manner. Ozone transforms first CaO into CaO_2, a change which, according to my recent experiments, a number of basic oxides undergo within an ozonized atmosphere. The oxides of manganese, lead, cobalt, nickel, and silver, for instance, are readily transformed by ozone into their corresponding peroxides. Whilst peroxide of calcium is formed, ozone exerts an oxidizing influence also upon the nitrogen contained in atmospheric air, and forms NO_4, which uniting to CaO_2, produces what we call nitrate of lime.

The fact, that electrical sparks passing through a moist mixture of oxygen and nitrogen generate nitric acid, was first ascertained by CAVENDISH, 1785; in 1840 I made the observation that under the same circumstances ozone is produced. DAVY has found that traces of nitric acid are formed around the positive electrode if a current passes through water containing atmospheric air or nitrogen, and I have ascertained that under the same circumstances ozone is generated.

From the facts above stated, it appears that during the slow combustion which phosphorus undergoes in moist atmospheric air nitric acid is formed, and we are now well aware that ozone makes its appearance at the same time. The invariable concomitance of the two phenomena mentioned, *i. e.* the contemporary formation of nitric acid and ozone which takes place under circumstances apparently so very different from each other, gives room to suspect that the production of one of those compounds is in some way or other connected with the generation of the other.

As electrical sparks are able to produce ozone out of moist and otherwise pure oxygen, it appears that the formation of that substance is entirely independent of the generation of nitric acid, and it becomes highly probable that the ozone produced, under electrical influence, out of moist atmospheric air has nothing to do with the nitrogen of the atmosphere. Now if ozone be capable of forming nitrate of lime by being treated both with nitrogen and hydrate of lime, it is very possible that ozone coming in the very moment of its formation in contact with nitrogen and water, produces what is called hydrate of nitric acid. Nitrogen being oxidized by ozone into NO_4, this compound would unite with an equivalent of HO_2 (ozone) and form hydrated nitric acids.

According to that view, the nitric acid generated,—

1. On electrifying moist atmospheric air ;
2. On electrolysing water containing nitrogen, *i. e.* air ;
3. On making phosphorus to act upon a moist mixture of oxygen and nitrogen ;

would be formed in a secondary way, that is to say, in consequence of the oxidizing effects produced by ozone upon nitrogen.

Supposing the suspected connexion really exists between the formation of ozone and the generation of nitric acid, we can easily understand the concomitant appearance of both, and conceive that where ozone is produced, nitric acid also must be formed, provided there be nitrogen and water present at the spot where ozone happens to be generated. If, agreeably to the views hitherto developed, the nitric acid formed on electrifying moist atmospheric air; electrolysing water charged with some azote; or making phosphorus to act on a moist mixture of oxygen and nitrogen, owes its origin to the ozone being produced under those circumstances, what is the cause of the generation of that acid which is formed during the putrefaction of azotic substances being in contact with strong bases and air? The putrefaction of those substances consisting, as it is well known, partly at least, in an act of oxidation or slow combustion of their oxidable constituent parts, and it being a fact that during the slow combustion of phosphorus, vapour of ether, or alcohol in atmospheric air, a highly oxidizing agent (ozone) makes its appearance, we may be allowed to compare the slow combustion of phosphorus with the putrefaction of azotic organic matters, both of them taking place in the atmosphere. And if it be a fact that during the slow combustion of phosphorus and ether, ozone is produced, it does not seem to be an over-bold conjecture to suppose that ozone is also formed during the putrefaction of azotic substances, and the nitrogen of those matters oxidized into nitric acid. As phosphorus which contains no trace of nitrogen, nevertheless forms nitric acid on its being slowly burned in atmospheric air, it seems to be not impossible that organic substances containing no nitrogen produce also ozone, and along with it nitric acid during the slow oxidation they undergo in atmospheric air. It seems to me to be important to ascertain, by accurate experiments, whether, under the circumstances last mentioned, nitric acid or nitrates are formed. Some observations made by Braconnot and Saussure seem to speak in favour of such a formation, they are however too vague to decide the question. To arrive at certainty regarding that fact is important, not only with respect to the theory of spontaneous nitrification, but also with reference to a matter which has of late been the subject of much discussion.

From what source does the vegetable world draw the nitrogen which we meet in so many of her products? If, according to a prevailing notion, it be only nitrogen in a compound state that can be assimilated by plants, is it not possible that nitrogen contained in nitrates might be as well taken up by them as the azote of ammonia? It is easy to see that in the affirmative case some nitrogen would be offered to growing plants by the means of organic substances containing no azote, and putrefying in the atmosphere. I do not intend, however, to meddle with those transcendent questions of physiological chemistry, and leave the answering of them to those who are much better qualified than myself to solve problems of such an intricate and difficult nature.

Bâle, October 1845.

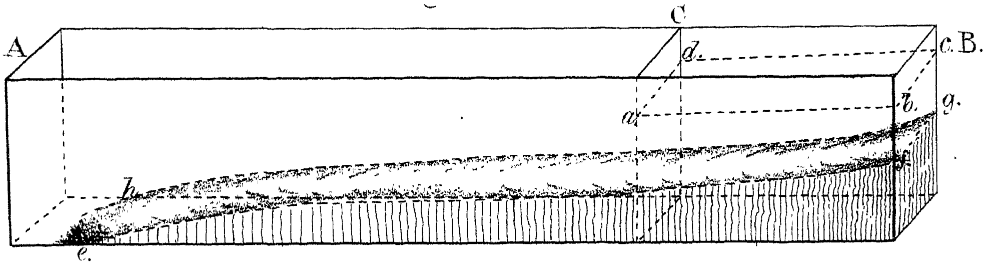


Fig. 2. p 144.

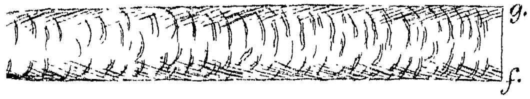


Fig 3. p. 144.

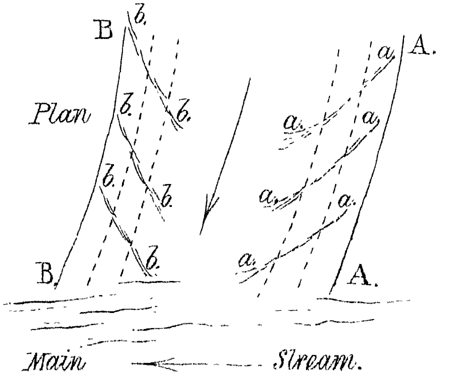
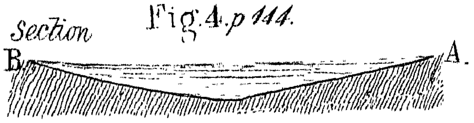


Fig. 4. p 144.



AA.BB. *Sides of Stream.*

a a. b b. Predominant ripple. The dotted Lines shew the direction of floating bodies exactly parallel to the sides.

Fig. 5. p. 151.

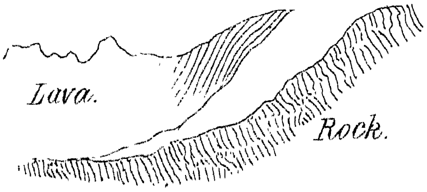


Fig. 6. p. 151.

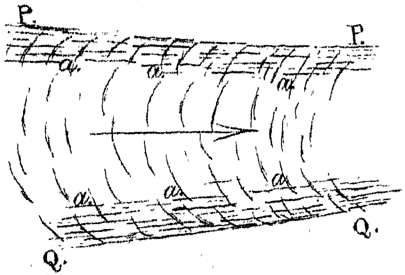


Fig 7. *Section. p. 151.*

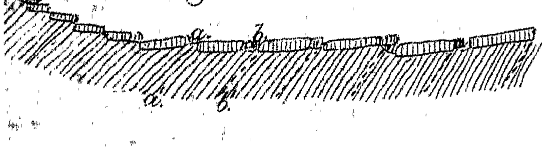


Fig. 8. *Ground Plan. p. 151.*

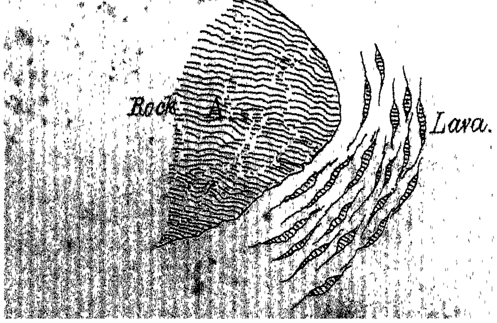
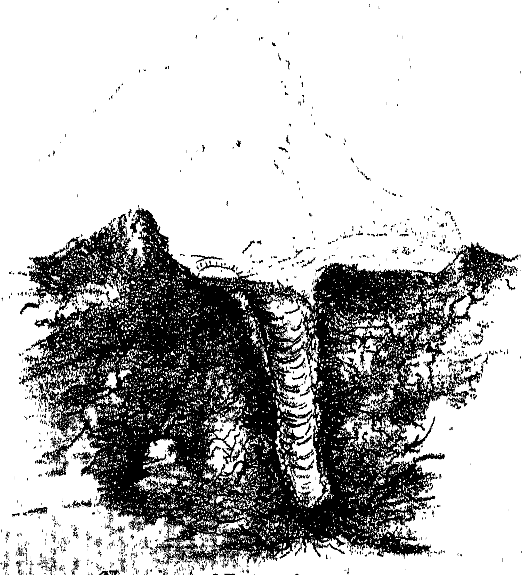


Fig. 9.



Glacier of La Gria, on [illegible]

XII. *Illustrations of the Viscous Theory of Glacier Motion.*

Part I. *Containing Experiments on the Flow of Plastic Bodies, and Observations on the Phenomena of Lava Streams.*

By JAMES D. FORBES, *Esq., F.R.SS. L. and E., Corresponding Member of the Institute of France, and Professor of Natural Philosophy in the University of Edinburgh.*

Received March 15,—Read April 10, 1845.

§ 1. *Plastic Models.*
§ 2. *Analogy of Glaciers to Lava Streams.*
Note on the Velocity of Lava.

§ 1. *Plastic Models.*

IN the concluding chapter of my "Travels in the Alps of Savoy," I have shown how the obscure relations of the parts of a semifluid or viscous mass in motion (such as I have attempted to prove that the glaciers may be compared to) may be illustrated by experiment.

The larger models, these described and figured, showed very clearly the precise effects of friction upon the motion of such a mass. They were formed of plaster of Paris, mixed with glue, and run in irregular channels, and the relative velocities of the top and bottom, the sides and centre of such a pasty mass were displayed by the alternating layers of two coloured pastes, which were successively poured in at the head of the model valleys. The boundaries of the coloured pastes were squeezed by the mutual pressures into greatly elongated curves whose convexity was in the direction of motion; and in a vertical medial section, the retardation of the bottom and the mutual action of the posterior and anterior parts, shaped the bounding surface of two colours into a spoon-like form.

Now these models convey a very palpable commentary upon the effects of friction on a plastic mass, and likewise on the influence of the mutual pressures of its parts; but in further illustration of the same thing I constructed another model, only executed as the printing of my volume approached its close, and which is cursorily described in a long note (page 377)*, whence its real importance may perhaps have been pretty generally overlooked.

The models in question, of which I have since made many, are formed by accumulating in one end of a long narrow box, AB, Plate IV. fig. 1, a deep pool of the viscid material already mentioned, which is retained there by a sluice or partition C which may be withdrawn at pleasure.

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* In this paper reference is of course made to the first edition of my "Travels," the second not having been then published.

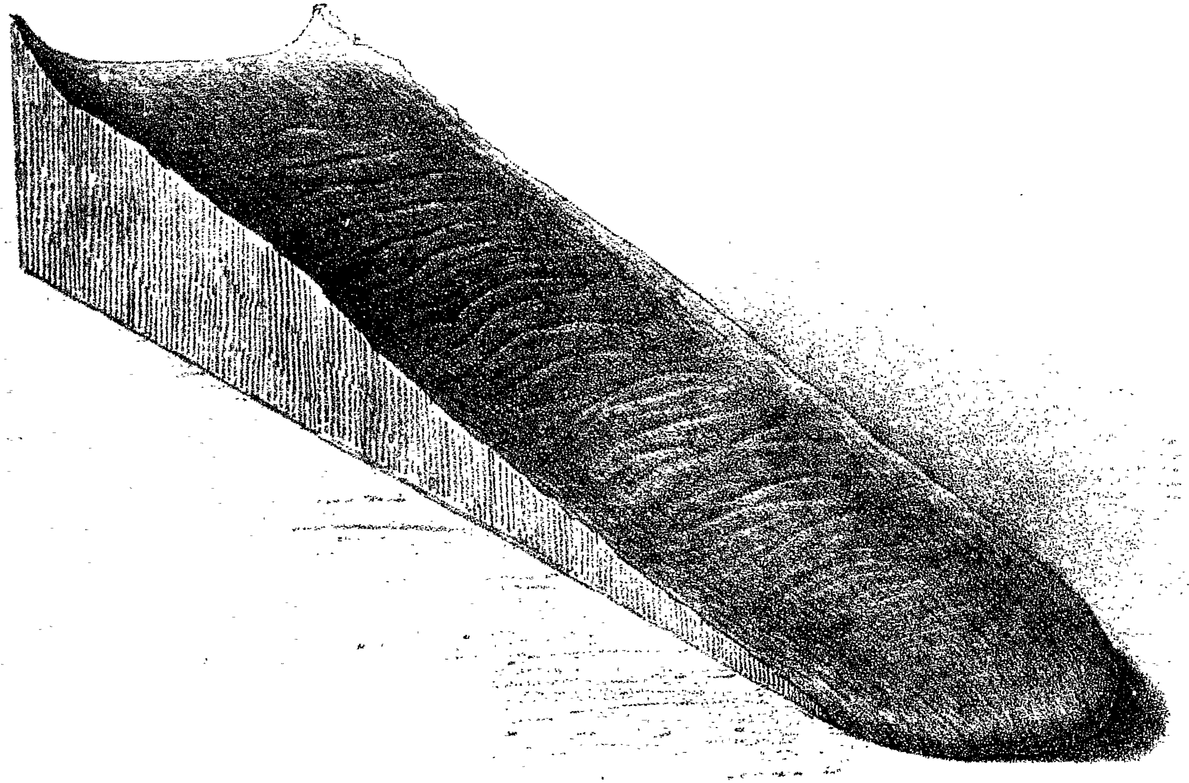
The surface of the pool *abcd* is then pretty thickly dusted over with a coloured powder, and the sluice is withdrawn.

The pasty mass subsides slowly under its own weight into the lengthened form *efgh*. The film of colour on the surface is therefore broken up so as to cover three or four times the surface it did at first; and its new distribution marks the lines of greatest separation of the superficial particles of the mass. The appearance of such a model when *run* is shown in fig. 2, and it manifests in the plainest manner the twofold tendency to separation in such a case where the channel is narrow and confined, and there is a certain mass of matter in front. Plate V. shows a more accurate drawing taken from such a model.

The lines of *sliding* separation occur most distinctly marked near the sides, where the friction is greatest, and the central parts are *forced past* the lateral parts, on account of the less embarrassed and consequently swifter motion of the centre; and they incline to the centre although the breadth of the channel be perfectly uniform. But the forces which tear asunder the parts (when such exists) act *perpendicularly to the former* and produce dislocations and fissures, which perfectly correspond to the direction and appearance of the crevasses of a glacier, that is, they are convex upwards or towards the origin of the glacier. It is the former of these lines of separation, or *differential motion*, which constitute and trace out with an exact parallelism the *veined structure* which I have described as forming the normal structure of all true glaciers. Plate V. is a representation of a very beautiful plaster model of more consistence than the other, in which the swelling of the surface and the direction of the open cracks produced by direct thrusts are most beautifully shown; and are even more so in the model than in the engraving. The fissures are transverse and slightly convex to the origin in the higher part of the glacier, then gradually turning round they radiate from a centre in the lower part, exactly as in the glacier of Arolla (Travels in the Alps, Plate VI.), and in all similar cases.

The experiment above detailed was suggested to me by studying the ripple of streams of water, which appear to have the same origin: and in very weak currents moving through very smooth and uniform channels (as the chiseled sides of water conduits) the same may be made manifest by throwing a handful of light powder on the surface, which then becomes divided into threads of particles inclined in the manner I have described at a certain angle from the side towards the centre, depending on the velocity of the stream.

The slightest prominence of any kind in the wall of such a conduit, a bit of wood or tuft of grass is sufficient to produce a well-marked ripple-streak, from the side towards the centre, depending upon the sudden and violent retardation of the lateral streamlets and the freer central ones being momentarily edged away from them. The general course of the motion of the particles is, however, scarcely affected by



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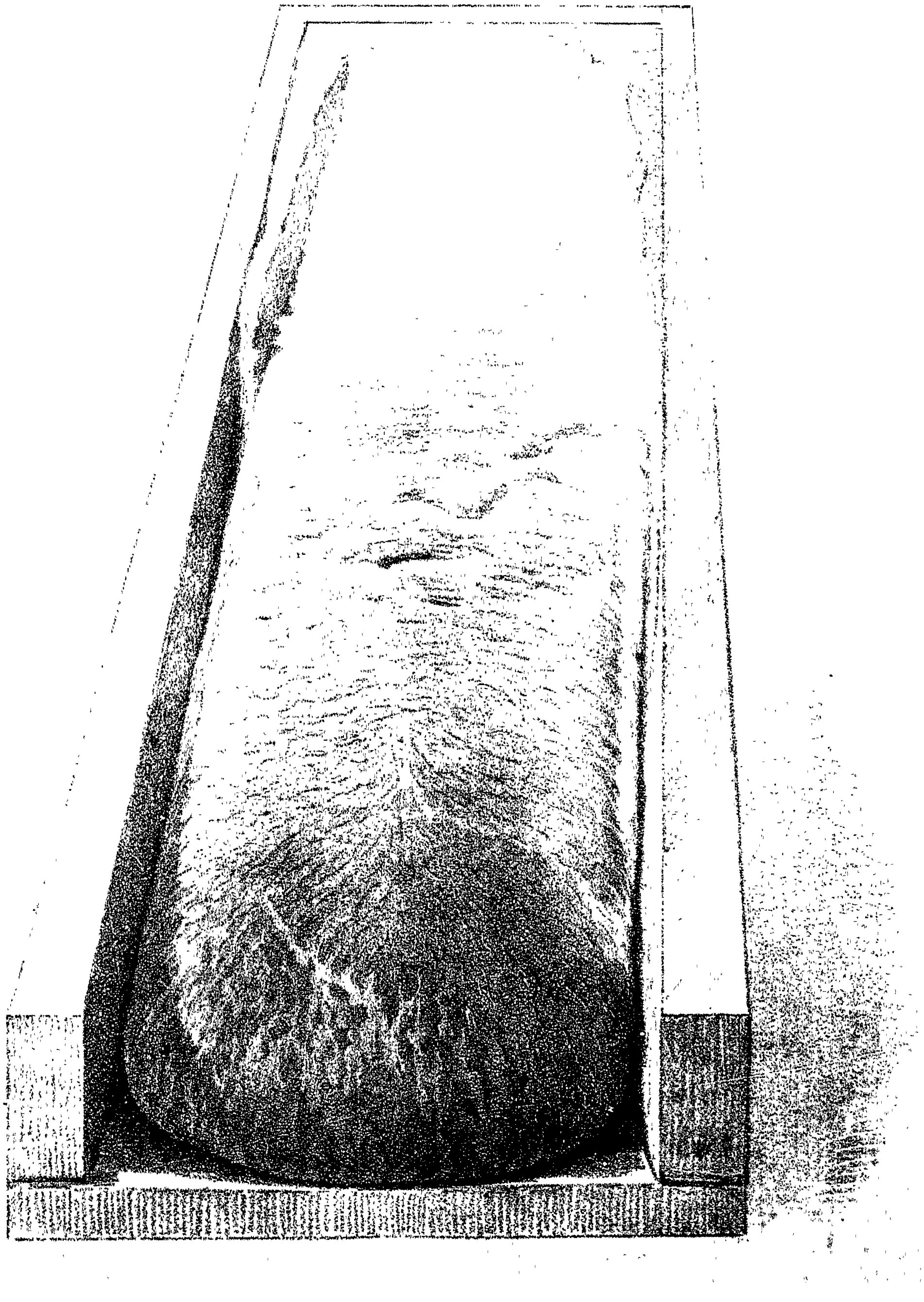

such a circumstance, for the differential velocities which cause the ripple and the separation, are always small compared to the absolute velocity of the stream; and thus a floating body on the water (just as the moraine on the glacier) perseveres in its course parallel to the side with scarcely any perceptible disturbance. When however the descent is violent and the friction great, floating bodies are gradually drawn towards the centre, and this happens also in exactly the same circumstances to the moraine of the glacier. Plate IV. figs. 3 and 4, shows the relation of the ripple-marks to the channel of a very flat smooth gutter in one of the side streets of Pisa, sketched after heavy rain.

These ripple-marks in water are well seen near the piers of a bridge, or when a post is inserted in a stream and makes a fan-shaped mark in the water cleft by it: such marks have been much neglected by writers on hydraulics; but in one of the most ancient hydraulic treatises, that of LEONARDO DA VINCI, lately printed from the MS. in the Italian collection of writers on hydraulics, they are very well described and figured. A case parallel to the last-mentioned, where a fixed obstacle cleaves a descending stream and leaves its trace in the fan-shaped tail, is well seen in several glaciers, as in that at Ferpêcle, and the Glacier de Lys on the south side of Monte Rosa, particularly the last, where the veined structure follows the law just mentioned. And I desire here to record that the views just presented as to the origin of the veined structure of ice, were confirmed, but were not suggested, by the experiments on viscous fluids just mentioned. The necessity of the tearing up of a solid mass, if it moved at all in a bed presenting insurmountable resistances on all sides, in directions such as the veined structure presents, was foreseen by me whilst dwelling amongst the glaciers themselves, at a distance from books or the means of experiment. The following extract from my Third Letter to Professor JAMESON, written in 1842 from the remote village of Zermatt, contains the substance of all that I have since developed and illustrated at greater length and in different ways rather to meet the difficulties of others, than to confirm what was plainly fixed in my own mind.

"The glacier struggles between a condition of fluidity and rigidity. It cannot obey the law of semi-fluid progression (maximum velocity at the centre, which is no hypothesis in the case of glaciers, but a fact), without a solution of continuity perpendicular to its sides. If two persons hold a sheet of paper so as to be tense, by the four corners, and one move two adjacent corners, whilst the other two remain at rest or move less fast, the tendency will be to tear the paper into shreds parallel to the motion; in the glacier the fissures thus formed are filled with percolated water, which is then frozen. It accords with this view,—1st, that the glacier moves fastest in the centre, and that the loop of the curve described coincides (by observation) with the line of swiftest motion. 2nd. That the bands are least distinct near the centre, for there the difference of velocity of two adjacent stripes parallel to the length of the glacier is nearly nothing; but near the sides, where the retardation is greatest, it is a maximum. 3rd. It accords with direct observation that the *differ* *ence* of velocity of the centre and sides is greater near the lower extremity of the glacier, and that the velocity is more nearly uniform in the higher part; this corresponds to the less elongated forms of the loops in the upper part of the glacier. 4th. In the highest part of such glaciers, as the curves become less bent the structure also vanishes. 5th. In the wide saucer-shaped glaciers which descend from mountain slopes, the velocity being as in shallow rivers nearly uniform across their breadth, no vertical structure is developed. On the other hand, the friction of the base determines an apparent stratification, parallel to the slope down which they fall. 6th. It also follows immediately (assuming it as a fact very probable, but still to be proved, that the deepest part of the glacier moves slower than the surface) that the *frontal dip* of the structural planes of all glaciers diminishes towards their inferior extremity, where it approaches zero, or even inclines outwards, since then the whole pressure of the semi-fluid mass is unsustained by any barrier, and the velocity varies (probably in a rapid progression) with the distance from the soil; whilst nearer the origin of the glacier the frontal dip is great, because the mass of the glacier forms a virtual barrier in advance, and the structure is comparatively indistinct, for the same reason that the transverse structure is indistinct, viz. that the neighbouring horizontal prisms of ice move with nearly a common velocity. 7th. Where two glaciers unite, it is a fact that the structure immediately becomes more developed. This arises from the increased velocity, as well as friction of each due to lateral compression. 8th. The veined structure invariably tends to disappear when a glacier becomes so crevassed as to lose horizontal cohesion, as when it is divided into pyramidal masses. Now this immediately follows from our theory; for as soon as lateral cohesion is destroyed, any determinate inequality of motion ceases; each mass moves singly, and the structure disappears very gradually*."

“In explaining the theory of the veined structure at a meeting of the Royal Society of Edinburgh on the 20th of March 1843, I stated that I had arrived at the conclusion that crevasses resulting from tension in certain parts of a glacier, must be formed at right angles to the surfaces of discontinuity or structural veins where they intersect the surface: a law conformable to the empirical one discovered by me on the glacier of the Rhone in 1841†, since generalized in other cases, and which even the adversaries of my theoretical views have admitted to be a correct statement of the facts‡.

My attention was at that time (March 1843) turned by my learned and acute friend Mr. W. A. CADELL, to the veined structure of the slag of iron furnaces as due to the difference of velocity of the parts producing surfaces of separation and peculiar molecular condition. The transition was easy to the case of volcanic rocks and lava

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[*] Third Letter on Glaciers, Edinburgh Philosophical Journal, October 1842.

[†] Edinburgh Philosophical Journal, January 1842.

[‡] Bibliothèque Universelle, tome xliv. p. 153. “C'est en effet un fait assez général que les bandes bleues coupent à angle droit les crevasses,” &c.

streams, and this case was pressed on my attention by an unexpected journey which I soon after undertook to Italy and Sicily.

§ 2. *Analogy of Glaciers to Lava Streams.*

There is something pleasing to the imagination in the unexpected analogies presented by a torrent of fiery lava and the icy stream of a glacier. But when we look upon the comparison historically and critically, and find how generally this analogy has been perceived and adverted to by persons of very different views and talents of observation, we are strongly tempted to suspect that some latent cause confers the marked resemblance.

This cause I of course consider to be the laws and condition of their motion, the struggle of a semi-fluid mass of enormous weight creeping down a mountain side, in which fluidity and solidity are so curiously combined, that we should be at a loss in either case how to name it; a straining, crackling, splintering solid, heaved on by the internal energy of the latent fluidity which pervades it, and which at last succeeds in giving to the general character of the motion and the moving mass, those of fluid bodies subject to the law of gravity; whilst the parts, themselves almost rigid, have that rigidity most fantastically subjected to the action of the dominant principle.

In illustration of what has now been said, I shall quote passages from some authors which, without particular research, have come under my notice expressive of the analogy just mentioned.

Mrs. Starke, the author of a well-known guide book of Italy, published many years ago, speaks of having seen near the crater of Vesuvius in 1818, "five distinct streams of fire issuing from two mouths, and rolling wave after wave slowly down the mountain with the same noise (?) and in the same manner *as the melting glaciers roll into the valley of Chamouni*; indeed this awful and extraordinary scene would have brought to mind the Montanvert, had it not been for the crimson glare and excessive heat of the surrounding scoriæ *."

Mr. Auldjo, an intrepid alpine traveller, writing about Vesuvius, in 1832, says, "The field of lava in the interior of the crater, inclosed within a lofty and irregular bank, might be likened to a lake whose agitated waves had been suddenly petrified; and in many respects resembles the *Mers de Glace*, or level glaciers of Switzerland, although in its origin and materials so very different †." And the view in the same work of "streams of lava on the south-east of the cone" presents a perfect analogy to a glacier, bearing on its surface three medial and two lateral moraines.

Captain Basil Hall, writing of Vesuvius at a later period, uses these remarkable expressions whilst describing an eruption of lava:—"The colour of this stream was a brilliant pink, much brighter at the sides than in the middle, where either from the cooling of the surface, or the accumulation of cinders and broken pieces of stone, a

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[*] Starke's Traveller's Guide, Ninth Edition, p. 293.

[†] Auldjo's Sketches of Vesuvius, p. 10, published 1833.

sort of dark ridge or backbone was visible from end to end, not unlike the moraine on the top of a glacier. This reminds me of a curious analogy which often struck me, between two objects so dissimilar as a glacier and a lava stream. They are both, more or less, frozen rivers; they both obey the law of gravitation with great reluctance, being essentially so sluggish, that although they both move along the bottoms of valleys with a force well nigh irresistible, their motion is sometimes scarcely perceptible*." This remarkable passage, worded with the usual scrupulous care of the author, combined with his account of the mechanism of a glacier in the description of the glacier of Miage in the same work, show that he had arrived at more correct notions on the subject than any of his contemporaries; notions which chiefly required careful observation to give them the force of demonstration. The allusion to *moraines* as characteristic of lava streams as well as glaciers, in the preceding extract, is perfectly borne out by the view of the lava of 1831 given by Mr. AULDJO and already cited; the same appearance is mentioned by M. ELIE DE BEAUMONT in his account of Etna in the following terms: "Une des circonstances que les coulées de lava présentent le plus invariablement * * * * consiste en ce que chaque coulée est flanquée de part et d'autre par une digue de scories accumulées qui rapellent par sa forme la moraine d'un glacier, * * * souvent aussi les coulées présentent de pareilles digues vers leur milieu, lorsqu'elles sont partagées en plusieurs courants distincts coulant l'un à coté de l'autre†."

In another place the same author compares the movement of the upper crust of the lava to that of glaciers according to the then prevalent theory:—"L'écorce supérieure d'une coulée separée de l'écorce inférieure et du sol sousjacent par une certaine épaisseur de lave liquide, ou du moins visqueuse, se trouve dans un état comparable à celui d'un glacier, qui, ne pouvant adhérer au sol sousjacent à cause de la fusion continuelle de sa couche inférieure, se trouve contraint de glisser‡."

Finally, M. RENDU, Bishop of Annecy, in his excellent Essay on Glaciers, refers in one passage (and I believe in one only) to the possible analogy with a lava stream; 'S[le glacier] s'affaisse-t-il sur lui-même pour couler le long des pentes comme le ferait une lave à la fois ductile et liquide§?"

The following considerations seem to show more than a general external analogy between lava streams and glaciers.

Their velocities are sometimes equally slow. Although common lava is nearly as liquid as melted iron, when it issues from the orifice of the crater, its fluidity rapidly diminishes, and as it becomes more and more burdened by the consolidated slag through which it has to force its way, its velocity of motion diminishes in an almost

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[*] Patchwork, by Captain HALL, vol. iii. p. 118, published 1841.

[†] Recherches sur le Mont Etna, p. 184. Published in the Mémoires pour servir à une Description Géologique de la France, tome iv. 1838.

[‡] Ibid. p. 177.

[§] Théorie des Glaciers, Mém. de l'Académie de Savoie, tome x. p. 93, published 1841.

inconceivable degree, and at length, when it ceases to present the slightest external trace of fluidity, its movement can only be ascertained by careful and repeated observations, just as in the case of a glacier. In November 1843, I watched lava issuing rapidly from a small mouth in the crater of Vesuvius at the rate of about one foot in a second. The eruption of Etna in 1832 advanced at the rate of five miles in two days, which is at the rate of one foot in about six seconds*. We may contrast with this the eruption of Etna in 1614, which yielded a lava which advanced but two miles in *ten* years according to DOLOMIEU†, during the whole of which time its motion was sensible. This gives a mean rate of rather more than three feet per day; but at the conclusion it was no doubt much slower.

Mr. SCROPE‡ saw the lava of 1819 in the Val del Bove moving down a considerable slope at the rate of a yard a day, nine months after its eruption. It had, he adds, the appearance of a huge heap of rough cinders; its progression was marked by a crackling noise due to friction and straining, and "on the whole was fitted to produce *any other idea than that of fluidity*. In fact," he continues, "we must represent to ourselves the mode in which the crystalline particles of lava move amongst one another, rather as a sliding or slipping of their plane surfaces over each other, facilitated by the intervention of the elastic (?) fluid, than as the rotatory movement which actuates the molecules of most other liquids." It is generally conformable to this view that we find in HAMILTON's *Campi Phlegræi* (fol. 1. 38. *Note*) the curious remark that some lava is so incoherent, or whilst fluid has so little *viscosity*, that in issuing from the volcano (Vesuvius) it has appeared "*farinaceous*, the particles separating as they forced their way out, just like meal coming from under the grindstones."

From all this it is quite clear that the seeming rapidity of the parts of a glacier, or the slowness of its motion, cannot be taken as the slightest evidence of its moving otherwise than as a fluid, contending with the *rigor* of the parts which include and resist the moving force, which is truly hydrostatic though limited in its exercise.

It is manifestly futile and unphilosophical to seek one *cause* of motion in a lava which, like that of Vesuvius in 1805, must have described as many hundred feet in a *minute* as that of 1614 from Etna probably did in a *year*§; for the *mean* daily motion of the latter during *ten years* was three feet; but toward the end of that time it must evidently have had for a long period an average motion of one-half or one-quarter of this, and therefore below the observed mean movements of certain glaciers. Fluidity, in the first instance as in the second, was the propelling vehicle or manner in which gravity acted, and this is a sufficient answer to any attempt to maintain that the plasticity of a glacier is a collateral but not a primary cause of motion,—a distinction surely without a difference.

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* E. DE BEAUMONT, Recherches sur le Mont Etna.

† Quoted by E. DE BEAUMONT, p. 85. The original is in the Journal de Physique, vol. i. of the New Series, where it is mentioned that the same slowness of motion has been observed in lavas of Vesuvius. FERRARA (Descrizione del Etna. Palermo, 1818) denies this statement, but not I think on sufficient grounds.

‡ On Volcanoes, p. 102.

§ See Note on the Velocity of Lava Streams at the end of this paper.

As in the case of all imperfect fluids, the central and superficial particles move faster than the lateral and inferior ones; and when the fluidity is *exceedingly* imperfect, as in those long-flowing lavas, there must be a rupture of continuity between the parts to permit them to slide and jostle past one another. This is evidently the cause of the noise referred to by Mr. Scrope and other writers. This tearing up of the stream into longitudinal stripes, occasioned by the varying velocity of the parts, is thus described by M. Dufrenoy in his account of Vesuvius: “La plupart des coulées présentent des bandes longitudinales assez parallèles entre elles: ces larges stries saillantes sur la surface sont les traces du mouvement de la lave qui ne s’avance pas d’une seule pièce, mais par bandes parallèles[*].”

And M. Elie de Beaumont describes a lava stream at Etna in these terms: “La surface offrait de profondes cannelures parallèles entre elles, dirigées dans le sens du mouvement qui l’avoit déversée à l’extérieur et qui étaient croisées par *de nombreuses gerçures transversales*[†].” Here then is evidently the twofold system of rents and perpendicular fissures described in the commencement of this paper as being found in the models, and as being conformable to the phenomena of glaciers.

During the winter 1843–44 which I spent in Italy, I had an opportunity of testing these resemblances, and tracing others to glaciers in the lavas of Vesuvius and Etna. I entered on the inquiry with a very jealous care of being drawn into the admission of fanciful or imperfect analogies; and I shall confine myself to the statement of one or two most plain and undeniable confirmations, selected from the results of many fatiguing rambles.

The plastic nature of the viscous lavas of Vesuvius and Etna is such as well might obliterate any internal traces of rents due to differential velocity, which, in the mass, are speedily closed and reunited as in a stream of treacle, or in the plaster models before explained, where the interior is homogeneous and the superficial coating above is permanently dislocated.

In lavas the indescribable ruggedness of the surface very generally prevents any record of the gentler play of forces. The following facts appear to me quite conclusive as to the manner in which a mass partially solidified, yet moving as a fluid, is torn up by the interior forces which act upon it.

1. At Vesuvius, the *Fossa della Vetrana* between the Hermitage and Monte Somma, is a valley lined with the lava of 1751. I here observed that the lava was in some places detached from the wall of the valley, leaving a cavity on the sheltered side of a projecting elbow of rock, just as a glacier does in similar circumstances, showing the considerable consistence which the lava possessed.

In the upper part of this Fossa the lava has a distinct linear structure where broken, in shells parallel to the sides, whose thickness varies from one-third of an inch upwards. The position of these surfaces of dislocation is indicated (for illustration) in figure 5 of Plate IV.

2. In the vast lava wastes of Etna, we encounter not only a greater extent of surface, but a greater variety of condition as to cohesion of the lava streams, and the slope down which it has descended, and thus we have a better chance of meeting with specimens of the manner in which the semi-solid crust of a lava stream is torn up and crevassed by the effect of gravity compelling it into the circumstances of fluid motion. From this tendency of all lavas to form slags, and of these slags to be splintered, tossed, and remoulded by the action of the still liquid portion of the stream below or around, not one-thousandth of the surface bears marks of the simple condition of fluidity under which it was originally moulded; and though when viewed from a distance, and in connexion with the form of the ground over which it has passed, we see plainly enough that it has *flowed* like a stream, the absence of any trace of easy undulating forms which characterise fluids or plastic masses, give to the *sciarre* of Etna (the *cheires* of Auvergne) an appearance far more removed from pristine fluidity than the glacier masses of Switzerland.

In traversing many miles of lava wastes between Nicolosi and Zafarana, on the eastern slope of Etna, I met with one singularly favourable specimen of a branch of a stream consolidated exactly as it had moved, and undisturbed afterwards. It is the part of the current of 1763, called *Lava delle Cerve.* The branch stream in question may be ten yards wide, and presents a thin crust, which has floated on the viscid lava below, and which, while yet imperfectly solidified, has been urged to move with the rest of the stream, and has undergone a process of division and rending accordingly. The stream has flowed in the direction from left to right in figure 6. The lateral parts PP, QQ have been *literally torn to pieces longitudinally* (as I wrote on my note-book on the spot) by the multiplied rents which showed the dislocation of the quicker moving central from the lateral parts, and these rents *inclined towards the centre of the stream in the direction in which it moved.* The length of the stream was divided by transverse rents strikingly convex towards the origin of the stream, as shown in the same figure. These cracks were marked by another peculiarity; the cake of floating scoria had not only been cracked across but pushed *upwards,* generally *forwards and upwards,* before it was finally included in the cooling mass of the stream; the result was the arrangement shown in the longitudinal section, fig. 7, which it will be seen resembles the tiling of a house, only that the fractured parts do not always overlap, but the anterior edge is tilted upwards. It will thus be seen that this tendency to separation acts also in the *vertical* plane, and the dotted lines aa', bb', &c. indicate the direction of its action, coinciding with the surfaces of differential motion, which produce what I have called the *frontal dip* of the veined structure of the ice of glaciers.

3. At no great distance from this lava, and near the foot of the hillock called the Serra Pizzuta, between the last-named point and the valley of Tripodo, I observed a *transverse* section of a lava stream exhibiting an arrangement in bands or plates, nearly parallel to the side of the current, but inclining towards the centre.

4. Between Zafarana and the Porta Calanna (Etna), a remarkably pretty illustration occurs in the surface of an old lava stream, worn and polished by the action of a brook. Where the lava has had to turn an abrupt corner of a rock, A, figure 8 (which represents a ground plan), the progress of the lava being violently checked by the resistance of the projecting mass, has been torn up into longitudinal shreds, which from imperfect fluidity have not reunited, but have left open cavities of the form represented in the figure, which exhibit with remarkable fidelity the forms of the fissures with which glaciers are sometimes traversed, when they are subjected to sudden transitions in their states of motion (as in the glacier des Bossons at Chamouni), and which coincide in direction with the veined structure, and pass into it by imperceptible gradations.

5. What I have called the *frontal dip* of the veined structure in glaciers*, I have explained by the accumulation of a sluggish mass of considerable extent upon a floor or bed offering the resistance of intense friction; in consequence of which the mass of ice, urged downwards and forwards by its intense weight, being resisted by the friction of that which immediately precedes it, must yield in the direction of least resistance, or squeeze itself in a slanting direction forwards and *upwards*, and thus sliding over the resisting mass immediately in front, will produce surfaces of discontinuity or differential velocity in that direction. Such a result I inferred from general principles without reference to any particular example, and the explanation of the superficial convexity of the lower part of many glaciers was evidently satisfactorily explained by it.

The convex swelling form of a viscous stream will depend principally upon the relative measure of two quantities, the stiffness or viscosity of the fluid, and the inclination of the surface; although it will also depend on the part of the stream, whether near the origin or the termination, which we consider.

I have found this variation from concave to convex, depending upon circumstances, alike in glaciers and lava streams. Some very highly inclined small glaciers existing at considerable heights, and therefore very hard and consistent, are, nevertheless, deeply concave from end to end, the slope compensating for the stiffness of the matter; such is a beautiful glacier, named, as far as I can learn, La Gria, or Glacier de Bourget, which descends from the Aiguille de Gouté towards the valley of Chamouni. See Plate IV. fig. 9.

Many, perhaps most, lava streams, where they have well-determined banks, are concave during the longer part of their course, but towards their termination they become convex as their viscosity increases. Nevertheless, I have seen portions of well-bounded streams decidedly convex.

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* See my Travels in the Alps, 1st Edit. pp. 167, 376, and letter to Dr. WHEWELL in JAMESON's Journal,

The appearance of the termination of a lava stream approaches strikingly that of a glacier. But this is much more than a vague analogy, and the accounts of faithful eye-witnesses prove the resisted motion of the doughy stream to be such as I anticipated. We find it explicitly stated over and over again in the writings of Dolomieu[*] and Della Torre[†] (and more particularly by the latter), that when a lava stream meets with any obstacle in front which checks its course, or when its course is checked by its own sluggishness, the stream swells, and gains gradually in thickness by the fluid pressure from behind urging its particles *forwards* and *upwards*. So striking was this natural effect of semi-fluid pressure, that these old observers attributed it to a peculiar force developed in the lava, of the nature of "fermentation," producing intumescence, the only way by which they could account for the vertical rise of the fluid, although it was very evident that the result was only what might be expected from the nature of the lava. It was also observed that when the lava stream had thus attained a certain height, it began to move on again, the necessary result of the increased hydrostatic pressure, although attributed by the authors named to the heat developed by chemical action. The tenacity with which the idea was long adhered to, that the residual fluidity of a nearly cooled lava stream was insufficient to account for its progress, without attributing to it the qualities of a second volcanic focus, are curious proofs of how long a palpable cause may be rejected as insufficient to explain a phenomenon, and a totally imaginary one superadded[‡].

I may add, that lava streams sometimes push their extremities *up hill*[§]; glaciers do the same.

In addition to the considerations already stated, which illustrate the viscous theory of glaciers, I am glad to avail myself of two which have reached me from independent and impartial sources.

The first is by Mr. Darwin, who in a small book on "Volcanic Islands," published about the time that I was engaged in making the preceding observations on Etna and Vesuvius, pointed out in a very clear manner the explanation which the veined structure of glaciers lends to that of volcanic rocks belonging to the Trachytic and Obsidian Series, where the lamination, instead of being obscure and rare, as it generally is in the Augitic lavas, owing perhaps to their greater fluidity, and more viscid and homogeneous texture, is the general rule. "The most probable explanation," says Mr. Darwin, "of the laminated structure of these felspathic rocks appears to be that they have been stretched whilst flowing slowly onwards in a pasty condition, in precisely the same manner as Professor Forbes believes that the ice of moving glaciers is stretched and fissured. In both cases the zones may be compared to the finest agates; in both they extend in the direction in which the mass has flowed, and those exposed on the surface are generally vertical[*]."

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[*] Papers in the Journal de Physique.

[†] Histoire du Vésuve. Naples, 1771, 8vo, p. 207–9, and several other places.

[‡] See the view of the termination of a lava stream in Auldjo's Sketches of Vesuvius, facing p. 92. The reader may also compare the view of a grotto in the lava, in the same work, with that of the source of the Arveiron, in my Travels, p. 387.

[§] Hamilton, Campi Phlegræi, folio, vol. i. p. 40, *note*.

The other illustration is contained in a communication with which I have been favoured by Mr. Gordon, Professor of Civil Engineering in Glasgow, and which has been printed in the Philosophical Magazine for March 1845, to which therefore I may refer. I need only state at present that it demonstrates, from observations on the flow of Stockholm pitch with a speed wholly insensible, and which requires some months for its accomplishment even in small masses, that a motion, of the nature of fluid motion, takes place at temperatures at which the pitch remains so hard as to be fragile throughout, and presents angular fragments with a conchoidal fracture. Mr. Gordon adds, that the resistance of the pitch to its own forward motion produces bands of differential velocity and having the *frontal dip*.

Edinburgh, February 26, 1845.

Note on the Velocity of Lava, referred to in p. 149.

The following are a few facts which I have collected on the velocity of lava. That of Vesuvius in 1805 appears to be the most fluid on record. Von Buch, who was in company with MM. de Humboldt and Gay-Lussac, describes it as shooting suddenly before their eyes from top to bottom of the *cone* in one single instant[†], which must correspond to a velocity of many hundred feet in a few seconds without interpreting it literally. Melograms, quoted by Breislak[‡], says it described three miles in four minutes, or about seventy-five feet per second *at a mean*. The same lava, when it reached the level road at Torre del Greco, moved at the rate of only eighteen inches per minute, or three-tenths of an inch per second[§]. The lava of 1794 (Vesuvius) reached the sea, a distance of 12,961 feet, in six hours, or passed over one-third of a mile per hour, or eight inches per second[||]; whilst the lava of Etna, in 1651, described sixteen miles in twenty-four hours, or above a foot per second the whole way. That of 1669 (Etna), which destroyed Catania, described the first thirteen miles of its course in twenty days, or at the rate of 162 feet per hour, but required twenty-three days for the last two miles, giving a velocity of twenty-two feet per hour[¶]; and we learn from Dolomieu, that this same stream moved during part of its course at the rate of 1500 feet an hour, and in others took several days to cover a few yards[*].

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[*] Darwin on Volcanic Islands, 1844. The whole passage, pp. 65–72, illustrates this analogy.

[†] Bibliothèque Britanique, vol. xxx. The vertical height of the cone proper is 700 or 800 feet; the length of the slope may therefore be 1300 feet.

[‡] Institutions Géologiques, iii. 142.

[§] Nicholson's Journal, vol. xii.

[||] Breislak, Campanie, i. 203.

[¶] Ferrara, Descr. del Etna, p. 105. This appears from the dates, though at variance with one assertion of the author.

The lava of 1753 (Vesuvius), starting with a velocity of 2500 feet per hour, soon diminished to sixty feet[†], as did that of 1754 to the same[‡]; and of 1766 to thirty feet per hour[§]. The lava of 1831 (Vesuvius) moved over 3600 feet in twenty-six hours, and finally advanced steadily at the rate of ten feet an hour[||]. The lava of Etna of November 1843, is said to have moved over three paces per second at the distance of a mile from the crater.

The stream of 1761 (Vesuvius), before it stopped flowing, advanced but three yards a day[¶]; and that of 1766, which continued moving for about nine months, moved over but a small space in that time. Had the attention of authors been equally directed to the *slow* as to the rapid advancement of lava, there is no doubt that we should find many instances besides these recorded by Dolomieu and Scrope, of continuous movements of three feet, and even one foot a day, or less.

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[*] Dolomieu Isles Ponces, p. 286. Note.

[†] Della Torre, Histoire, &c., p. 196.

[‡] Ibid. p. 130.

[§] Hamilton, Campi Phlegræi, i. 19.

[||] Auldjo, Sketches of Vesuvius, p. 79, with a sketch of the front of the stream whilst advancing at this rate.

[¶] Della Torre, p. 182.

XIII. *Illustrations of the Viscous Theory of Glacier Motion.*

Part II. *An attempt to establish by observation the Plasticity of Glacier Ice.*

By JAMES D. FORBES, *Esq., F.R.S.S. L. and E., Corresponding Member of the Institute of France, and Professor of Natural Philosophy in the University of Edinburgh.*

Received July 28, 1845,—Read January 15, 1846.

§ 3. DE SAUSSURE'S *Theory.*
§ 4. *Modifications of* DE SAUSSURE'S *Theory.*
§ 5. *Experiments at Chamouni on the Plasticity of Ice.*

§ 3. DE SAUSSURE'S *Theory.*

WHEN GRUNER proposed the explanation of glacier motion by the sliding of the ice over its bed, and DE SAUSSURE illustrated and confirmed it by considerations drawn from the lubricating action of the earth's heat melting the ice in contact with the soil[*], there is no reason to suppose that either of them thought it necessary to take into account the varying form of the channel through which the glacier had to pass, and the consequently invincible barrier presented to the passage of a rigid cake of ice through a strait or narrow aperture when it occurred. This is the more remarkable, because he conceives that the *inequalities of the bed or bottom* may be overcome by the hydrostatic pressure of the water, which he supposes may be imprisoned between the rock and the ice, so as absolutely to heave the latter over the resisting obstacles.

I believe that in no part of DE SAUSSURE'S writings will there be found any, the slightest reference to the possibility of the glacier when fairly formed *moulding* itself to the inequalities of the surfaces over which gravity urges it; nor is there any trace of the correlative fact of an unequal motion of the sides and centre of the ice, which may in some sense be considered as the geometrical statement of the preceding physical fact. The fact of plasticity was suspected by BASIL HALL, and more distinctly announced by RENDU, as shown in the first part of this paper; but it could not be proved until the geometrical fact of the swifter motion of the centre of the glacier relatively to the sides was established in 1842[†]. The contrary opinion at that time generally entertained would have been conclusive against the hypothesis of plasticity called forth by the gravity of the mass.

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[*] To do GRUNER justice, he appears to have been aware of the effects of the earth's heat and the lubricating action of the water thawed from the glacier: "Lorsque les côtés de l'amas [de glace] qui touchent la montagne, fondent en entier, toute la masse entraînée par son poids glisse sur son fond et s'avance dans la vallée," French translation, p. 333 . . . "il est vraisemblable que leur surface inférieure [*i. e.* des glaciers] se liquéfie autant, et peut-être plus que la supérieure," ib. p. 289.

[†] Edinburgh Philosophical Journal, October 1842, and Travels in the Alps of Savoy, p. 134.

So far, then, as appears from his writings, De Saussure considered the ice of glaciers to constitute a mass possessing rigidity in the highest degree, such rigidity in short as common experience assigns to ice tranquilly frozen in small masses, which is sensibly inflexible. It is in this sense in which I have spoken of De Saussure's sliding theory, as one which "supposes the mass of the glacier to be a rigid one sliding over its trough or bed in the manner of solid bodies*," and I adhere to the definition as excluding the introduction of the smallest flexibility or plasticity, to which the term rigidity is correctly opposed. I consider too that De Saussure's theory supposes the mass of the glacier to slide over its trough or bed in the manner of *solid* bodies, that is, not as a heap of rubbish or absolute fragments, such as a glacier sometimes precipitates over a rock, but which evidently did not enter into De Saussure's explanation, nor, in fact, required any theory.

As to the crevasses which form so prominent a feature of many glaciers (although many are in parts almost devoid of them), I do not recollect that De Saussure alludes to them as *facilitating* in any way the movement of the glacier, but simply as *results* of its motion and of the rigid character of ice. And I believe that this view (whether it was held by De Saussure or not) is substantially correct. The regular system of crevasses of a glacier is approximately transverse, rather arched upwards towards the origin of the glacier, and as De Saussure supposes the glacier to be pressed downwards by the mass of snow accumulating at its head, it is hard to believe that he could have regarded these fissures as in any way essential to its movement, even were they very numerous; the tendency of such a pressure from above would rather seem to be to pack the ice like an arch, opposing its convex side to the direction of the pressure.

The view now given of De Saussure's theory of glacier motion is not only conformable to what may be gathered from his writings, but expresses the unanimous understanding of his numerous commentators, followers and opponents. As some doubt has lately been hinted as to the definiteness of De Saussure's conception of a glacier as a mass devoid of flexibility and plasticity and urged down a slope *as a whole*, by the lubricating action of fusion in contact with the soil to an extent which, in extreme cases, might even give it the character of buoyancy, I will take the liberty of quoting some indisputable authorities amongst writers of name in different countries. And first from De Saussure himself:—

"La chaleur de la terre fait fondre les neiges et les glaces, même pendant les froids les plus rigoureux lorsque leur épaisseur est assez grande pour préserver du froid exterieur les fonds sur lesquels elles réposent."—*Voyages*, § 532. *** "C'est elle qui entretient les torrents, qui, même pendant les plus grands froids, ne discontinuent jamais de sortir de tous les grands glaciers." § 533. ***

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* Travels, p. 362.

"Presque tous les glaciers reposent sur des fonds inclinés; et tous ceux d'une grandeur un peu considérable ont au-dessous d'eux, même en hiver, des courans d'eau qui coulent entre la glace et le fond qui la porte. On comprend donc que ces masses glacées, entraînée par la pente du fond sur lequel elles reposent, dégagées par les eaux de la liaison qu'elles pourraient contracter avec ce même fond, soulevées même quelquefois par ces eaux, doivent peu à peu glisser et déscendre en suivant la pente des vallées, ou des croupes qu'elles couvrent." § 535.

"Quand on considère que ces glaces reposent sur des plans inclinés, qu'il coule sous elles des torrens d'eaux qui les fondent par en bas, les détachent et les soulevent, ne sent-on pas que leur permanence dans la même place est une chose *physiquement impossible*?" § 2284.

Ramond's account:

"La cause [de la marche des glaciers] est facile à concevoir: une masse qui pèse sur un plan incliné tend nécessairement à déscendre, et cette tendance est favorisée dans les glaciers par le choc des torrents qui roulent sous leur voûtes, par l'humidité que leur masse communique au terrain qui les porte, enfin par cette multitude innombrable de cavités qui creusent leur partie inférieure, et dont l'effet est de diminuer le frottement en diminuant l'étendue des surfaces[*]."

Elie de Beaumont's account of De Saussure's theory: speaking of the lava of Etna, he says, "L'écorce supérieure d'une coulée separée de l'écorce inférieure et du sol sousjacent par une certain épaisseur de lave liquide, ou du moins visqueuse, se trouve dans un état comparable à celui d'un glacier, qui, ne pouvant adhérer au sol sousjacent à cause de la fusion continuelle de la couche inférieure se trouve contraint à glisser[†]."

Bischoff's account:

"Das jährliche Vorrücken der Gletscher welches Saussure ganz einfach aus einem allmäligen Herunterrutschen der unteren durch das Aufthauen des Eises schlüpfrig gewordenen Seite des Gletschers auf der schiefen Fläche des Bodens erklärt, ist eine bekannte Thatsache[‡]."

Agassiz's account:

"Autrefois on admettait tout simplement qu'ils glissaient sur leur fond, en vertu de leur propre pesanteur, et que ce glissement était favorisé par les eaux au fond de leur lit. C'était l'opinion de Saussure[§]."

Martins' account:

"De Saussure, Escher de la Linth, André de Luc, attribuent cette progression au poids des glaces et à l'affaissement produit par la fonte de la face inférieure qui repose sur le sol[‖]."

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[*] Voyages en Suisse par Coxe, traduit par Ramond, ii. 119, 1790.

[†] Mémoires pour servir à la Déscription Géologique de la France, iv. 177, published 1838.

[‡] Wärmelehre, p. 180, published 1837.

[§] Etudes sur les Glaciers, p. 152, published 1840.

[‖] Sur les Glaciers de Spitzberg. Bibliothèque Universelle, 1840, tom. xxviii. p. 166.

Studer's account:

"Die bisher fast allgemein herrschende Theorie erklärte die Bewegung der Gletscher aus der Schwere allein. Es soll die Gletschermasse als STARRER KÖRPER auf ihrer Felsgrundlage, wie auf einer schiefen Ebene, theils durch ihr eigenes Gewicht theils durch dem Druck der höheren Eis- und Firnmasse herunter gleiten (Gruner, Ramond, Kuhn, De Saussure, Escher)*."

This last testimony of the most exact and most learned of the living Swiss geologists as to the sense in which De Saussure's theory has always been understood is so important that I shall add a translation: "The hitherto generally prevailing theory explains the movement of the glaciers by gravity alone. The glacier masses are considered as RIGID BODIES, which slide down over their rocky beds partly by their own weight, partly under the pressure of the higher ice and *névé*." My interpretation of the views of De Saussure as regards the rigidity of the glacier ice is thus borne out by an independent authority, for M. Studer's work and my own appeared simultaneously. It is further confirmed by private communication with another eminent Swiss naturalist nearly connected by relationship with De Saussure himself, who is more intimately acquainted with the opinions and writings of his illustrious kinsman than any other person now alive, and who considers that De Saussure's views were confined to the general analogy of the glaciers to solid masses sliding down inclined planes, and that the effects of the inequalities of the channels and forms of the ice-basins were not comprehended in his theory.

If we feel surprise that a naturalist and observer so eminent had not adverted to the difficulty of imagining a solid cake of ice, even though perfectly detached from its bed, to disengage itself from the obstacles and sinuosities of its rocky channel, we should remember,—*first*, that the explanation is given in the most general terms, and there is no appearance that its author looked more closely at its consequences and details than to satisfy himself that a sliding motion in the abstract was rendered possible by the action of the earth's proper heat, an ingenious and philosophical element of the theory (however inadequate), and that which being due principally to De Saussure, renders the theory properly his, and connected it with his ingenious inquiry into this curious part of physics as a distinct and wholly independent investigation. *Secondly*. Every one knows how an application of a principle so true and so ingenious leads men of even the most exact habits of thought to overlook difficulties in a subject almost unstudied. De Saussure did much for our knowledge of glaciers, and he saw much which no one had observed before him: we must not blame him if, yielding to a true and natural analogy of sliding bodies, he overlooked real and great difficulties inherent in the conception of a glacier as a solid continuous mass and highly rigid. *Thirdly*. In De Saussure's time no plan or map, worthy of the name, of any glacier existed, and this was a blank which even De Saussure did not attempt to supply. The popular notion of a glacier, which it is certain he had in his mind when he penned the passages which relate to their motion, is a mass of ice of small depth and considerable but uniform breadth sliding down a uniform valley, or pouring from a narrow valley into a wider one, as is the case with a vast majority of glaciers tolerably accessible, and which alone were visited at the time of publication of the first edition of the *Voyages dans les Alpes.* In all these cases the lateral resistance might easily be overlooked, and the popular comparison to one solid body sliding on another and lubricated by its own liquefaction might be accepted as a complete explanation; as has even been done at a later period by those who have attempted to illustrate De Saussure's theory by experiment, but who, like him, neglected the form and undulations of the bed in which it rests.

§ 4. *Modifications of* De Saussure's *Theory.*

De Saussure and his immediate followers appear to have considered the crevasses which occur transversely in most glaciers, as the result of the inequalities of the beds down which they are constrained to move; but other writers have imagined that the part which these crevasses perform in the phenomena of glacier motion is fundamental, and essential to the existence of the movement at all. Some writers have remarked that the fall of ice blocks over the precipice which often occurs near the lower end of glaciers, leaving the superior portions unsupported, allows them to advance to fill the position formerly occupied by the portion of the now fallen ice. But in this case it would appear that cause and effect are in some degree confounded. The ice about to be projected over the cliff must either advance towards its fall by its own gravity, or by the pressure of the parts behind. If its own gravity suffices, the same cause will urge the ice behind it to move similarly, whether the block in question fall or not; and if it be the pressure from behind which shoves it on, then still more is the pressure of the entire glacier the cause of motion of the entire glacier, irrespective of the precipitation of its more advanced part.

Thus, M. Martins' theory of the progression of glaciers is, that the weight of the parts causes them to separate by fissures into wedge-shaped masses, without their sliding along the bottom; that the fissures become filled with frozen snow, and that thus the glacier is perpetuated and extended year by year. "Cette progression," he says, "n'est donc ni un glissement ni un affaissement difficiles à comprendre, puisque la glace doit adhérer au sol, mais un démembrement successif*." Besides other objections, it is now universally admitted that the glacier-proper does not grow by the consolidation of snow in its fissures.

But setting aside the attempt to render the sliding motion of the entire glacier considered as a plane slab more easy, by considering the motions of the parts instead of the motion of the whole, we are led to notice the attempt to reconcile the sliding theory to recent observation, by ascribing to the crevasses of the glacier the important office of enabling it to accommodate itself to the inequalities of its channel.

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* Martins sur les Glaciers de Spitzberg et de la Suisse. Bibl. Univ. Juillet 1840.

Our object is, in this section, merely to state the view in its most plausible form, which in the succeeding section we shall controvert by experiments giving it a direct negative. In the third portion of this essay we shall enter more at large into the phenomena of crevasses, and mention other objections to this hypothesis and every modification of it.

According to this view, the friction of the ice against the sides of the valleys will produce a dislocation of the glacier into longitudinal stripes (as shown in Plate VII. fig. 1.[*]), where a transverse line bb' becomes by the irregular motions of the ice distorted into the zigzag form $hcc'h$. Or if we suppose the plasticity of the ice to be sensible, but that its action is accompanied with fractures, the abruptness of the angles of the figure will be softened, as in the broken line $lmm'l$ in the lower part of the same figure. This latter hypothesis evidently merges into the true plastic theory, when the part of the progression due to the flexure of the transverse lines bears a large proportion to the effect of the longitudinal slide, or more generally, when the surfaces of sliding or yielding become greatly multiplied, when the notched line will merge into a curve.

The passage of the glacier through a gorge or contraction is explained on the same view by figure 2, where the resistance of the sides having occasioned a series of parallel longitudinal rents as before, the portion of the glacier beyond the limits of breadth of the gorge BB' is supposed to be detained or embayed whilst the intermediate columns slip through.

§ 5. *Experiments at Chamouni on the Plasticity of Ice.*

It has been shown that in order to reconcile De Saussure's theory of sliding motion with the ascertained fact that the centre of the glacier moves faster than the sides, it had been assumed that solutions of continuity or longitudinal crevasses were formed parallel to the length of the glacier, by means of which the central portion slides past that adjacent to it, and so on for successive strips as we approach the sides; the more rapid retardation near the sides being rendered mechanically possible by the increased number of these longitudinal dislocations.

The result was therefore predicted to be that the glacier would be found to move by *echelons*, or that strips of ice of a certain number of feet, or yards, or fathoms, would move either suddenly or by gradual sliding, but at all events so as to mark by an abrupt separation at the longitudinal fissure, that the one portion of ice has slipped past the other by a distinct measurable quantity.

When I first learnt at Geneva, in August 1844, from Mr. Hopkins's published papers[†], that this was really the author's meaning, it occurred to me that the proof

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[*] These figures and their interpretation are taken from Mr. Hopkins's First Memoir in the Cambridge Transactions, vol. viii. part 1. A figure similar to the first is to be found in a more recent paper by the same author in the Philosophical Magazine for June 1845.

Fig. 1 p 162.

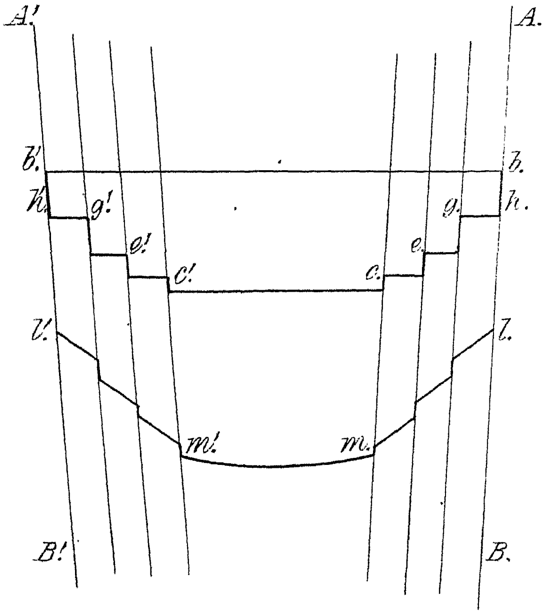
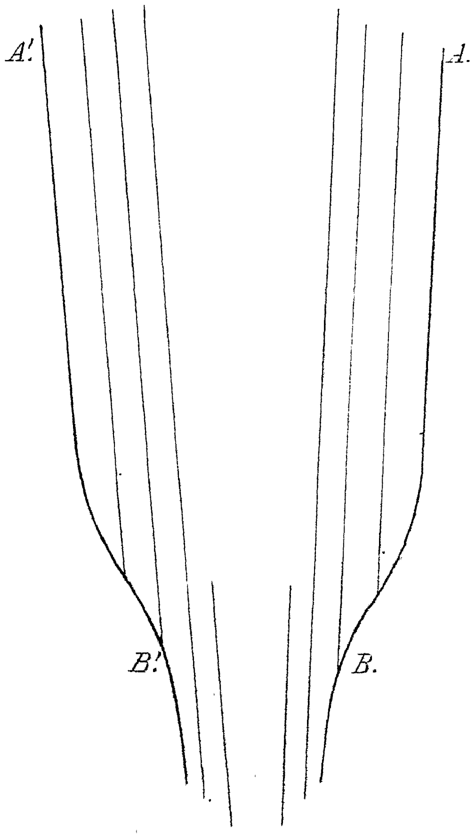


Fig. 2. p 162



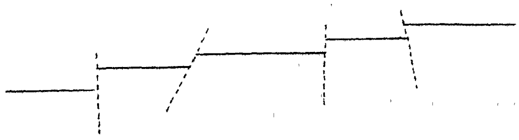


Fig. 3. p. 172.

between the rival theories was easy, and that it was only necessary to place a series of marks in a right line transversely to the glacier, and observe whether they were displaced by an imperceptible flexure, or whether they slid past one another by sudden dislocations.

Such a proof was independent of any assertion as to the existence or not of such fissures as those contended for, about which different opinions might be formed, especially as they might be asserted to exist although invisible to the eye. Being satisfied in my own mind of the non-existence of such fissures wherever the ice is not violently dislocated and descends a steep place in a tumultuous manner (which, as already mentioned, is not the case which we consider), I had no hesitation in predicting that the result of the experiment would be confirmatory of my theory, and contradictory of the other; that the transverse line would be found to become a continuous curve, and that no other system of fissures could be found in the glacier satisfying the mechanical postulate of the greater velocity of the central parts of the glacier, than the *ribboned structure* of the ice, which I had already pointed out as resulting from a forced separation of the semi-rigid ice, at a vast, though finite, number of points in the breadth of the glacier, and which I showed to exist exactly in the direction required for releasing the mass from the tension induced by the gravity of its parts.

Having gone to Chamouni a few days later, I looked out for a place where the ice should be as compact as possible, wholly devoid of open fissures, and if possible continuous up to the bank. This latter condition I found it impossible to fulfil on the Mer de Glace, at least without ascending to the *névé*, which might be objected to as less rigid than the glacier proper. The former condition was well-satisfied in a sort of bay on the west side of the Mer de Glace between the Angle and Trelaporte, exactly under the little glacier of Charmoz. The part adjoining the western shore of the glacier is indeed highly crevassed, and therefore unfit for this experiment; but at the distance of fifty or sixty yards from the moraine it becomes remarkably flat and compact for a space of about seventy yards in width, and several hundred yards in length, throughout which space there is not a single open crevasse. Now this compact area of ice presents the veined structure in a nearly longitudinal direction, with a degree of delicacy and distinctness not to be found in any other part of this glacier (as I had already remarked in my *Travels*, p. 159), and it contains no other trace of a system of longitudinal fissures or lines of separation of any kind, which could render mechanically possible the distortion of this flat compact surface of so great an extent. Now I have always observed that the veined structure near the side of a glacier is best developed where the ice is least crevassed, or the continuity of the mass most perfect,—a fact stated and referred to its true cause from the first date of my speculations on the origin of the blue veins, in the following words:—"The veined structure invariably tends to disappear when a glacier becomes so crevassed as to lose horizontal cohesion, as when it is divided into pyramidal masses. Now this immediately follows from our theory;

for as soon as lateral cohesion is destroyed, any determinate inequality of motion ceases, each mass moves singly, and the structure disappears very gradually*." Now the ice at the point in question is the compacted ice which has just passed round the great promontory of Trelaporte, having been rent by numberless chasms, and which is consolidated by pressure in the bay in question, whilst the centre of the glacier being still on the steep is deeply crevassed. The structure of the even ice is continuously striped with a regularity comparable to that of the finest chalcedony for a distance of some hundred feet. This structure must *have been produced on the spot,* since no such perfect structure exists higher up, and if it did, it must have retained all the marks of dislocation due to the formation and reconsolidation of the fissures, which are so numerous and wide as to render the passage of the glacier quite impracticable if we follow the same strip of ice up towards the promontory of Trelaporte. Let it then be recollected that the structure is *produced here,* under our eyes, on the very spot where the experiments about to be detailed were made, and that the structure in question produced a vertical slaty cleavage so distinct, that the ice broken into hand specimens may be split parallel to it like any slaty rock, and that the fine hard laminæ projecting vertically after the glacier has been washed by rain, permitted the blade of a knife to be thrust between them to a depth of several inches, although they are rarely more than a quarter of an inch thick.

I shall now describe the actual measurements made upon the glacier in order that my method of proceeding in similar cases (when I have only published results) may be understood.

The general position of the experimental surface will be understood from the topographical sketch (Plate VIII. fig. 1.) The theodolite was planted at a fixed point on the ice Q, just within the crevassed portion, which intervened between it and the western shore of the glacier. This point of fundamental and constant reference was fixed by an exactly vertical hole pierced with an iron *jumper,* or blasting iron, one inch in diameter, and was frequently deepened in order to preserve the centre as exactly as possible in the same vertical line in the ice. The theodolite was centred over it at every observation by means of a plummet, which nearly filled the cylindrical hole and permitted an adjustment, which one day with another might be accurate to about one-tenth of an inch. No stick was placed in the hole, but when not in use it was covered by a large flat stone, which effectually prevents congelation in ordinary weather†. The adjustment of the theodolite on the ice is always a matter for patience, but I succeeded in rendering it perfectly stable when once erected by inserting the three feet in cavities in the ice, and filling them carefully with ice chips,

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* Third Letter on Glaciers, Edinburgh Philosophical Journal, October 1842, and Appendix to Travels, 1st edit. p. 407.

† On one occasion, this precaution having been neglected (in the case of a different mark on the ice), the hole was found completely frozen up after exposure to a day or two of severe weather in the month of August. It was however recovered by observing the beautiful stellar form of the ice-crystallization.

Fig.1. p.164

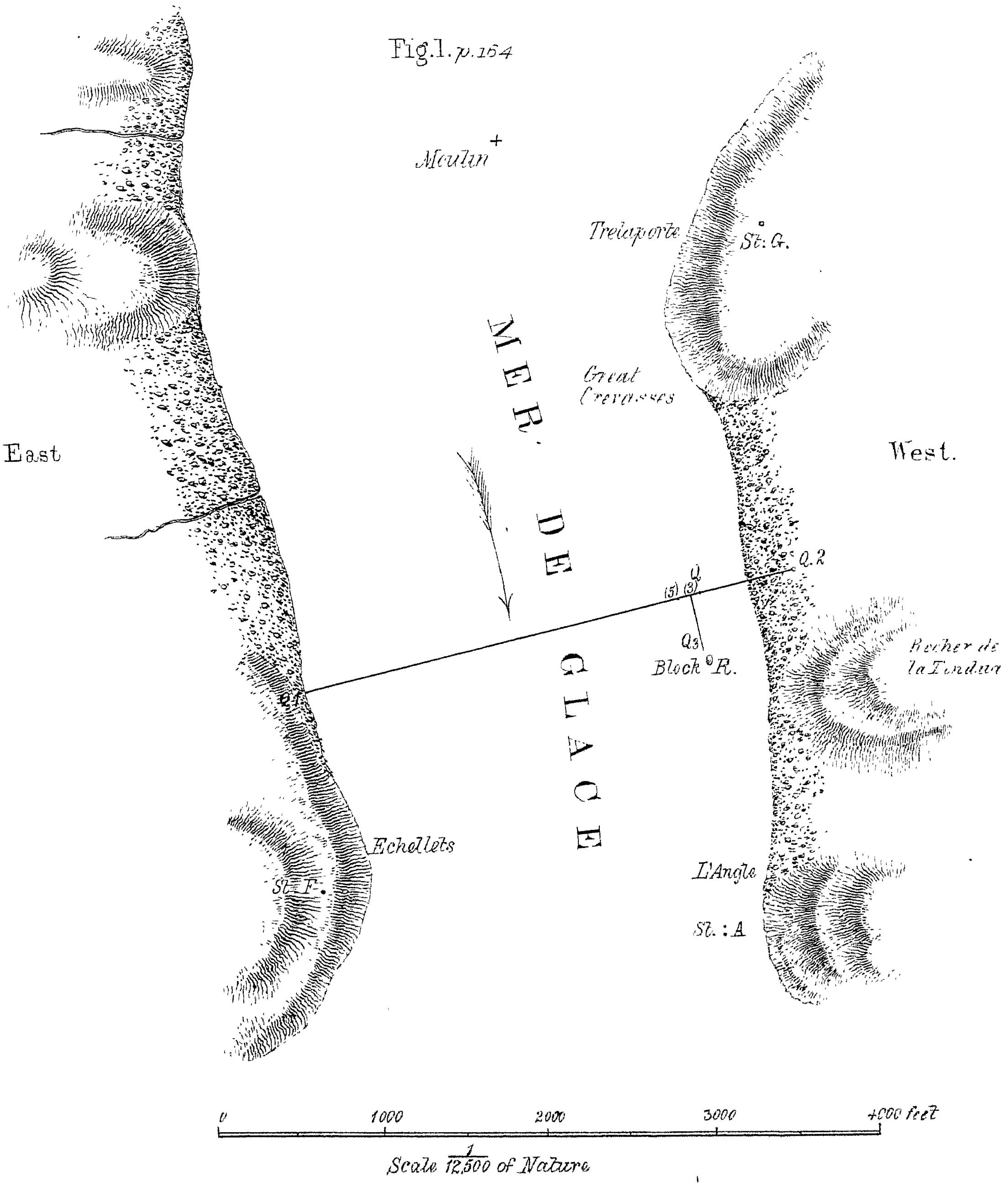
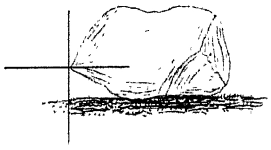
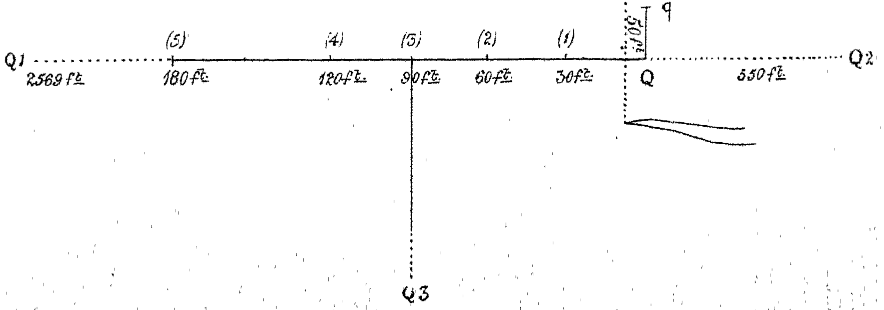


Fig.2. p 164.



Mark on les Echellets.

Fig.3. pp.165.169.



J. Basire lith.

The theodolite, placed at Q, was pointed with its vertical wire on the well-defined angle of an erratic block Q1 on the opposite eastern bank of the glacier, above Les Echellets (see Plate VIII. fig. 2.). By causing the telescope to traverse in a vertical circle, a transverse line joining the points Q, Q1 was determined, and several stations were fixed in the compact ice eastwards of Q, at distances from it of 30, 60, and 90 English feet and subsequently at 120 and 180 feet. These were numbered in succession (1), (2), (3), (4), (5), and the permanence of their positions in the ice was secured as before by carefully driving vertical holes two feet deep, which were occasionally deepened, and covered with flat stones when not in use. As these points were in succession nearer to the centre of the glacier, they were expected to move with gradually increasing velocity in advance of the imaginary line Q, Q1 drawn across the ice.

But as the theodolite stationed on the glacier at Q must partake of its motion whilst the mark Q1 on the bank remained at rest, the visual line QQ1 would appear to revolve *towards* the origin of the glacier, and hence the relative advance of the points (1), (2), &c. would seem too rapid. To estimate the correction for this error the velocity of the glacier at Q must be determined, and also the distance QQ1. For the former purpose the following method was adopted. When an observation at station Q had been completed, by pointing the telescope on Q1 and observing the apparent advance of the points (1), (2), &c., the telescope was reversed in the Y's, or turned 180° towards the western moraine, upon which it indicated from day to day a new position, owing to the angular revolution of the line joining the fixed point Q1 and the moveable point Q. The point Q2 in the topographical sketch (Plate VIII. fig. 1) indicates the point where the visual line touched the moraine at the commencement of the observations on the 9th of August 1844. By the application of a scale or a similar method, the apparent advance of Q referred to the moraine Q2 was regularly measured. It is thus obvious that these apparent motions were *too great* (by the property of diverging lines) in the ratio of the distance Q1.....Q2, to Q1.....Q: and hence it became necessary to ascertain the position of Q2 as well as Q1. For this purpose a base-line of 300 feet was measured on the ice parallel to the length of the glacier, or perpendicular to the transverse visual line, extending from the point marked (3) to the point Q3 in fig. 3, whence by the theodolite the following bearings were taken:—

	°	′
Q1	0	0
(3)	83	6
Q2	148	0

From which we deduce the distance from

Q1 to (3) . . . . 2479 feet.
(3) to Q2 . . . . 640 feet.

But as (3) is 90 feet east of Q, we have

Q.....Q1=2569 feet. Q.....Q2=550 feet.

The apparent motion of Q measured on the moraine is greater than the true motion in the ratio $\frac{2569+550}{2569}$ or $\frac{6}{5}$ nearly. The actual motion of Q is readily deduced as well as the apparent rotation of the visual line QQ1. Thus during 16·75 days, the duration of the experiment, the apparent advance of Q referred to the moraine Q2 was twenty-three feet six inches, which at the distance Q1.....Q2 (3119 feet) subtends an angle of 25′ 54″, or almost exactly *one and a half minutes daily.*

The motion of Q during the interval of any two observations of the marks (1), (2), (3), &c. being thus known, the correction applicable to the apparent advancement of the said marks beyond the visual line is at once found by the proportion

$$Q.....Q1 : Q\text{'s motion} :: Q.....(1) : E,$$

where E is the error of apparent position of mark (1). Thus, suppose the apparent motion on the moraine Q2 to be seventeen inches; this, reduced in the ratio of 6 : 5, gives 14·2 inches for the progress of Q. If the effect on the apparent place of a mark ninety feet from Q were required, we should have 2569 : 14·2 :: 90 : 0·50 inch.

I shall first detail the observations on the total motion of the glacier at Q, during the period to which the experiment extends, with the corrected daily motion and a memorandum of the state of the intervening weather, which accounts by its excessive variability for the remarkable variation of the progress of the glacier*.

TABLE I.

Date.	Interval.	*Apparent* motion from commencement.		*Corrected* daily rate.	Weather.
	days.	ft.	inch.	inch.	
August 9. 6 P.M.	0	0	0		9. Fine.
10. 3½ P.M.	0·90	1	5	15·6	10. Some rain. 11. Some rain.
12. 2 P.M.	1·94	4	0	13·2	12. Some rain. 13. Snow storm. 14. Some rain. 15. Snow storm. 16. Wet.
17. 2½ P.M.	5·02	11	6½	14·8	17. Fine; melting snow on glacier. 18. Showery. 19. Fine; snow still on glacier. 20. Very fine. 21. Very fine.
20. 1 P.M.	2·94	16	0	15·0	22. Rain.
23. 2 P.M.	3·04	19	10	12·5	23. Showery. 24. Cold rain. 25. Fine.
26. Noon.	2·92	23	6	11·8	26. Fine. Glacier dry.

The first three marks on the ice, those placed thirty, sixty, and ninety feet nearer the centre of the glacier than Q, were fixed on the 9th of August, the mark (4) at 120 feet was planted on the 17th, and the mark (5) at 180 feet, on the 19th. The following are the observations on the *apparent* motions of these points past the transversal line through Q, as well as these relative motions corrected for the real movement of the station Q, as explained in last page. To avoid an illusory appearance of accuracy, the results are given to the nearest twentieths of an inch, which is below the possible errors of observation.

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* See Travels in the Alps of Savoy, &c., p. 148.

TABLE II.

Table of the *Apparent* and *True* Motions of the Stations *relatively to Station Q.*

Date.	Interval.	Motion of Q.	Apparent relative motions.					True relative motions.				
			30 feet.	60 feet.	90 feet.	120 feet.	180 feet.	30 feet.	60 feet.	90 feet.	120 feet.	180 feet.
	days.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
August 9. 6 P.M.	0·0	0·0	0·0	0·0	0·0			0·0	0·0	0·0		
10. 3½ P.M.	0·90	14·0	0·8	1·9	2·3			0·65	1·6	1·8		
12. 2 P.M.	1·94	25·6	1·7	3·1	3·7			1·4	2·5	2·8		
14. 1 P.M.	1·96	29·0	1·5	2·8	4·3	0·0		1·15	2·1	3·25	0·0	
17. Noon............	2·96	44	2·1	4·0	6·0	7·1	0·0	1·6	2·95	4·45	5·0	0·0
19. 5 P.M.	2·21	33·2	1·7	2·7	4·4	6·2	8·5	1·4	2·1	3·25	4·75	6·15
23. 1 P.M.	3·83	48	2·5	5·8	7·7	10·3	15·0	1·95	4·7	6·05	8·15	11·75
26. Noon............	2·96	34·6	2·1	4·6	6·5	8·0	11·0	1·7	3·6	5·3	6·4	8·6
Motion from 9th to 26th...	16·76	228·4*						9·85	19·55	26·9		
Motion from 17th to 26th...	11·96	159·8						6·65	13·35	19·05	24·3	
Motion from 19th to 26th...	9·00	115·8						5·05	10·4	14·6	19·3	26·5

The results in the preceding Table have been divided into three periods, corresponding to the unequal times of observation of the last two and the first three stations. The first line of addition includes the motion at thirty, sixty, and ninety feet for nearly seventeen days; the second sum contains the comparative results for four stations throughout twelve days, and the last line contains the entire relative motions of five stations for nine days. These results may be further analysed, as in the following Table, which exhibits the mean daily motion in inches corresponding to each point for these distinct periods, and also the ratio of the relative motion of each point to the actual motion of the glacier at Q, or the zero point, during the same interval.

TABLE III.

Interval in days.	Actual motion of Q, or zero point.	(1.) 30 feet.		(2.) 60 feet.		(3.) 90 feet.		(4.) 120 feet.		(5.) 180 feet.	
		Mean daily relative motion.	Ratio to actual motion.	Daily relative motion.	Ratio to actual motion.	Daily relative motion.	Ratio to actual motion.	Daily relative motion.	Ratio to actual motion.	Daily relative motion.	Ratio to actual motion.
	inch.	inch.		inch.		inch.		inch.		inch.	
16·76	228·4	0·59	0·043	1·17	0·086	1·60	0·118				
11·96	159·8	0·56	0·042	1·12	0·084	1·59	0·119	2·03	0·152		
9·00	115·8	0·56	0·044	1·16	0·090	1·62	0·126	2·16	0·167	2·94	0·229

This Table shows, first, in a striking point of view, the regularity of action of the law by which the variable motion of the different transversal points in the glacier is governed; since the movement in the different intervals bears so near a proportion, that when estimated in terms of the actual motion of the glacier at the place, the relative motion of the parts scarcely differs by unity in the second place of decimals, and is generally much under it. Taking into account the inevitable errors of observation and the extraordinarily unfavourable circumstances of the weather, it is in the very highest degree improbable that this *law of continuity* of the *partial* motions can be accounted for by any casual justling or sliding of one finite portion of the ice past another, which would inevitably have left some of the points relatively at rest during some one of the many intervals of observation, and given to others evidence of a starting motion until friction had established a fresh position of repose amongst the struggling masses.

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* The true sum ought to be about four inches greater. The difference arises from the impossibility of estimating the correct velocities for the fractional intervals.

Secondly. This Table enables us to establish not only the continuity of motion of any one point, but the continuity of the relation which connects the points (1), (2), (3), &c. For instance, the relative motions of (1) being

·59 ·56 ·56,

and those of (2) being

1·17 1·12 1·16,

the ratios are

1·98 2·00 2·07.

In like manner the ratios between (3) and (2) will be found to be

1·37 1·42 1·44.

Thirdly. The flexure of the ice may be conveniently represented by a diagram, in which the several ordinates are set off corresponding to the relative spaces moved over. But to find the initial positions of the fourth and fifth marks, the proportional motion for the first period, when they were not observed, must be deduced from the comparative velocity of the period when the observations were comparable. Thus by Table II. the relative velocity of (3) to (4) during the time that they were observed together is 19·05 : 24·3; consequently whilst (3) moved over 26·9 inches (4) would have moved over 34·3 inches; the proportional motion for 16·75 days. In like manner for the mark (5) we have the simultaneous motions of (3) and (5) expressed by 14·6 inches and 26·5 inches, and hence by proportion, as before, we find

14·6 : 26·5 = 26·9 : 48·8 inches,

the relative motion of (5) in 16·75 days.

From these data the simultaneous relative motions of these six stations may be projected in a curve, or rather polygon, as shown in Plate IX. fig. 1. This is interesting, as showing very plainly, not only the regulated increase of swiftness of the glacier towards the centre, but that the *variation of the variation* is clearly brought out, indicated by a convexity in the direction of the motion, and confirming the general principle long ago announced by me, that the retardation is relatively greatest towards the side and less towards the centre. I appeal to any one conversant with the laws of mechanics in their practical application, whether the manifest continuity of such a law does not plainly include a continuity in the mutual action of the parts of the mass under experiment, and even independent of the manifest absence of great dislocations, would not establish the doctrine of a molecular yielding, or plasticity in the ice as opposed to the irregular justling of great blocks, admitting that such could exist unperceived.

The period through which this experiment extended (seventeen days) is conclusive against the idea that a small flexure could take place until the accumulated strain on the solid produced a rupture, which relieved the strain, and so forth, *per saltum*. The continuity of glacier motion in every case except that of precipitous descents or ice-falls, first proved by my experiments in 1842, is now universally admitted by those who have had any personal experience in the measurement of glacier motion, however opposed to my theoretical views*. The changes for seventeen days were connected (as has been shown) by a law of continuity established by numerous intervening observations; and the flexure or distortion of the ice amounted in this time to no less than *four feet* at the opposite ends of a line 180 feet in length. It is quite certain, from my own previous observations and those since made by M. Agassiz's directions on the glacier of the Aar, that the movement thus shown to have continued seventeen days without a *saltus* would have continued the whole season in the same manner. In fact, the *deformation* or flexure thus observed being sufficient to account for the whole excess of the central above the lateral motion, is in itself an explanation, and a proof that the explanation is adequate, and leaves nothing residual to be accounted for by *saltus*†.

I have more to add on this subject, but shall first give an account of an extension of this experiment on the actual flexure of the ice, upon so elaborate a scale as I scarcely ventured to hope would prove successful, especially as the time I could devote to watch its progress was small, and the circumstances of weather excessively unfavourable.

Having succeeded so well with the thirty feet station in the transverse line, I thought of multiplying the points of observation still further, so as to obtain a polygon of flexure more nearly approaching to a curve. This I did by making the first ninety feet of the transverse line, *i. e.* the space between Q and (3), Plate VIII. fig. 3, the subject of more immediate experiment, fixing in it forty-five stations only two feet apart. After several partial failures, which gave me, notwithstanding, encouraging results, I selected this plan. A space a foot wide and ninety feet long was cleared with hatchets and ice tools, so as to arrive at a nearly even surface of the hard delicately veined ice; and gutters were made so as to drain as far as possible the surface water from the part under experiment. The theodolite being stationed as usual over Q, and the vertical wire of the telescope describing a great circle passing through the line QQ1 transverse to the glacier, an assistant (Balmat), directed by my signals, bored a series of holes from two feet to two feet, forty-five in number, with a common carpenter's centre-bit, and as nearly as possible in the visual line. The holes, which were $\frac{5}{16}$th of an inch in diameter and about five inches deep, were immediately occupied by wooden pins prepared for the purpose. These pins were placed as nearly as possible in the visual straight line, but from the nature of the operation some errors were inevitable. The amount of these errors of position or zero of the marks was immediately determined by causing the vertical wire again to traverse the series, the assistant placing over the centre of the head of each pin in succession the zero point of a scale of inches divided both ways, and held parallel to the length of the glacier, so that (the divisions to tenths of an inch being very plainly marked, and divisible by estimation by the telescope) the fundamental position of each pin was determined, and considered as + if in advance of the transverse line (in the direction of the glacier's motion), and − if behind it (or nearer the origin of the glacier). The mere error of reading did not in any case exceed $\frac{1}{20}$th of an inch, though the uncertainty of centring of the theodolite over Q might amount to $\frac{1}{10}$th of an inch, or even more. The two marks nearest Q had their positions determined by a thread stretched from the station-pointer of the theodolite to the third mark, their distance being too small to be distinctly seen by the telescope.

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* See proofs cited in my Ninth Letter on Glaciers, Edinburgh Philosophical Journal, April 1845, and in second edition of Travels in the Alps, Appendix.

† Mr. Williamson, Fellow of Clare Hall, Cambridge, to whom I proposed this experimental test of the theory of movement by *echelons*, made a series of independent observations on the Mer de Glace, which coincided in result with what has been stated above. After a patient examination of these facts, and of others which he observed on different glaciers, I am glad to say that Mr. Williamson was led to abandon the theory of sliding columns or fragments, and to accept that of plasticity as connected with the mechanism of the veined structure which I have endeavoured to illustrate above.

The very same process, as regards the placing the zero of the scale on the head of the pin and reading off, was repeated on subsequent days, and the new readings *minus* the fundamental readings gave the *apparent* relative motion in the interval. This apparent motion had to be corrected, exactly as before explained, for the rotation of the visual line due to the translation of the fundamental point Q.

The following Table contains—(1.) the original readings on the four days of experiment, namely—

1844. August 20. 10 A.M.
August 21. 6 P.M.
August 23. 1 P.M.
August 26. 11 A.M.

(2.) The differences from the fundamental readings or total apparent displacements for each day, reckoning from the commencement. (3.) The same corrected for the rotation of the visual line from the following data:—

August.	Interval. days.	Motion of Q. inches.	Correction at dist. 90 feet. inches.
20 to 21	1·33	16	0·56
20 to 23	3·12	38	1·33
20 to 26	6·08	73	2·56

TABLE IV.—Showing the Apparent and True relative motions of forty-five points two feet apart, in a line transverse to the axis of the Mer de Glace, 1844.

	Readings of Position.				Apparent Motion.			Corrected Motion.			
Mark, No.	Aug. 20, 10 A.M.	Aug. 21, 6 P.M.	Aug. 23, 1 P.M.	Aug. 26, 11 AM.	August 20, 21.	August 20—23.	August 20—26.	August 20, 21.	August 20—23.	August 20—26.	Remarks.
1.	+0·15	−0·1	−0·25	0·0	−0·25	−0·4	− 0·15	−0·25	−0·45	−0·15	Between 1 and 2 a slight fissure.
2.	+0·3	−0·5	−0·25?	− 0·2	−0·8	−0·55	− 0·5	−0·8	−0·6	−0·55	
3.	+0·15	+0·15	+0·6	+ 0·7	0·0	+0·45	+ 0·55	−0·05	+0·35	+0·4	
4.	−0·2	−0·1	+0·25	+ 0·3	+0·1	+0·45	+ 0·5	+0·05	+0·35	+0·3	
5.	−0·25	−0·35	−0·05	+ 0·3	−0·1	+0·2	+ 0·55	−0·15	+0·05	+0·25	
6.	−0·25	0·0	+0·6	+ 1·2	+0·25	+0·85	+ 1·45	+0·2	+0·65	+1·1	
7.	−0·2	+0·2	+0·9	+ 1·8	+0·4	+1·1	+ 2·0	+0·3	+0·9	+1·6	Veined structure very strong.
8.	0·0	+0·3	+1·2	+ 2·45	+0·3	+1·2	+ 2·45	+0·2	+0·95	+2·0	
9.	0·0	+0·5	+1·45	+ 2·5	+0·5	+1·45	+ 2·5	+0·4	+1·2	+2·0	Between 9 and 10 a fissure.
10.	−0·2	+0·15	+1·1	+ 2·3	+0·35	+1·3	+ 2·5	+0·25	+1·0	+1·95	
11.	−0·4	+0·25	+1·35	+ 2·7	+0·65	+1·75	+ 3·1	+0·5	+1·4	+2·45	
12.	−0·0	+0·5	+1·6	+ 2·85	+0·5	+1·6	+ 2·85	+0·35	+1·25	+2·15	
13.	−0·55	+0·15	+1·45	+ 3·3	+0·7	+2·0	+ 3·85	+0·55	+1·6	+3·1	
14.	−0·55	+0·35	+1·5	+ 3·7	+0·9	+2·05	+ 4·25	+0·75	+1·65	+3·45	
15.	−0·15	+0·6	+2·05	+ 4·15	+0·75	+2·2	+ 4·3	+0·55	+1·75	+3·45	
16.	−0·2	+0·65	+2·2	+ 4·5	+0·85	+2·4	+ 4·7	+0·65	+1·9	+3·8	
17.	−0·25	+0·6	+2·2	+ 4·15	+0·85	+2·45	+ 4·4	+0·65	+1·95	+3·45	
18.	−0·15	+0·7	+2·4	+ 4·85	+0·85	+2·55	+ 5·0	+0·65	+2·0	+4·0	
19.	−0·1	+0·95	+2·5	+ 5·35	+1·05	+2·6	+ 5·45	+0·8	+2·05	+4·4	
20.	−0·15	+1·0	+3·0	+ 5·9	+1·15	+3·15	+ 6·05	+0·9	+2·55	+4·9	Two fissures between 19–20 and 20–21.
21.	+0·25	+1·7	+3·55	+ 6·7	+1·45	+3·3	+ 6·45	+1·2	+2·7	+5·25	
22.	+0·1	+1·6	+3·5	+ 6·7	+1·5	+3·4	+ 6·6	+1·25	+2·75	+5·35	
23.	+0·3	+1·7	+4·0	+ 7·55	+1·4	+3·7	+ 7·25	+1·1	+3·0	+5·95	22–23, slight fissure very oblique.
24.	+0·2	+1·65	+4·0	+ 7·9	+1·45	+3·8	+ 7·7	+1·15	+3·1	+6·35	
25.	−0·3	+1·15	+3·5	+ 8·0	+1·45	+3·8	+ 8·3	+1·15	+3·05	+6·9	
26.	+0·35	+1·7	+4·3	+ 7·95	+1·35	+3·95	+ 7·6	+1·05	+3·2	+6·1	26–27, a slight fissure. It recrosses the line at 40–41.
27.	+0·25	+1·75	+4·4	+ 8·45	+1·5	+4·15	+ 8·2	+1·2	+3·35	+6·65	
28.	+0·25	+2·05	+4·9	+ 9·1	+1·8	+4·65	+ 8·85	+1·45	+3·8	+7·25	
29.	+0·4	+2·2	+5·15	+ 9·35	+1·8	+4·75	+ 8·95	+1·45	+3·9	+7·3	
30.	+0·15	+1·9	+4·9	+ 9·3	+1·75	+4·75	+ 9·15	+1·4	+3·85	+7·45	
31.	0·0	+2·0	+4·7	+ 9·0	+2·0	+4·7	+ 9·0	+1·65	+3·8	+7·25	
32.	+0·2	+2·3	+5·3	+ 9·7	+2·1	+5·1	+ 9·5	+1·7	+4·15	+7·7	
33.	+0·2	+2·1	+5·5	+10·0	+1·9	+5·3	+ 9·8	+1·5	+4·3	+7·95	
34.	+0·9	+2·9	+6·0	+10·95	+2·0	+5·1	+10·05	+1·6	+4·1	+8·15	
35.	+0·25	+2·2	+5·7	+10·5	+1·95	+5·45	+10·25	+1·55	+4·4	+8·25	34–35, a very slight fissure.
36.	+0·1	+2·1	+5·5	+10·15	+2·0	+5·4	+10·05	+1·55	+4·35	+8·0	
37.	−0·1	+2·05	+5·3	+10·5	+2·15	+5·4	+10·6	+1·7	+4·3	+8·5	
38.	0·0	+2·1	+5·9	+11·3	+2·1	+5·9	+11·3	+1·65	+4·75	+9·15	
39.	+0·2	+2·4	+6·35	+11·8	+2·2	+6·15	+11·6	+1·75	+5·0	+9·4	
40.	0·0	+2·3	+5·9	+11·1	+2·3	+5·9	+11·1	+1·8	+4·7	+8·85	
41.	+0·1	+2·5	+6·4	+12·15	+2·4	+6·3	+12·05	+1·9	+5·1	+9·7	40–41. See 26–27.
42.	0·0	+2·3	+6·25	+11·8	+2·3	+6·25	+11·8	+1·8	+5·0	+9·4	
43.	−0·1	+2·2	+6·15	+11·65	+2·3	+6·25	+11·75	+1·8	+4·95	+9·3	
44.	0·0	+2·4	+6·5	+12·35	+2·4	+6·5	+12·35	+1·85	+5·2	+9·85	
45.	−0·2	+2·4	+6·1	+12·25	+2·6	+6·3	+12·45	+2·05	+4·95	+9·9	

The results of these observations will be best understood by consulting the projected results in Plate IX. fig. 2, in which the advance of the marks is magnified twofold relatively to the spaces between them, which was necessary for the reduced scale of the engraving, although it has the disadvantage of increasing the deviations from symmetry which might arise from errors of observation. As those who have not attempted the actual execution of such experiments cannot be aware of the difficulties they entail, it may be just to mention that during weather so unfavourable as that which occurred during the continuance of these experiments, nothing can be so irksome as the necessity of persevering in the face of physical obstacles, the only alternative which the necessary limitation of my stay afforded being to abandon them. I do not speak of the painful effort of conducting delicate observations for hours under a hot sun, whilst the feet are immersed in the liquid sludge of decaying snow, for I am not aware of having sacrificed the precision of a single observation to such a cause (though in the course of my glacier experience I have sometimes been compelled to abandon or discontinue observations), but it is easy to see that the success of experiments like this depended upon the absolute fixity of the marks inserted in the unstable and wasting surface of the glacier, and that the most dry and uniform condition of the ice seemed alone to promise a chance of finding the small pins in the exact positions in which they had been planted a day or two before. Instead of this, eleven out of nineteen days which I spent at Chamouni were wet, and notwithstanding the season of the year, the glacier was repeatedly covered with snow, which in melting under a succeeding fierce sun, left the surface honeycombed by infiltration and streaming with wet, so that the preservation of the holes was only effected by laboriously covering every one with large flat stones during the intervals of observation, and even this was not free from other disadvantages which it would take too long to particularize. On the whole, the uniformity of the triple curves exhibited in fig. 2 is surprising, considering the local errors to which the fixation of the pins was liable, and the smallness of the quantities sought. The first two curves, those for the 21st and 23rd August, are indeed as perfectly regular as it would be possible to expect from this kind of observation, even much more so than I had ever hoped to attain; but on the 26th the holes containing the pins were more degraded, and some manifest errors have arisen from this cause, and evidently affect only single marks, such as the twelfth and twenty-fifth mark, which singly have inclined forward or backward by the fusion of the ice. With these preliminaries as to the reasons why the irregularities of these curves should be judged with indulgence, I will state briefly the most apparent general results.

First. The flexure of the ice is proportional, almost exactly to the time elapsed in the intervals of the observations; and it is also graduated from point to point, not *staccato*, as would inevitably have been the case had the relative motion been due to the sliding of finite portions past one another, as in Plate VII. fig. 3. We perceive nothing of the kind.

Secondly. A singular peculiarity strikes the eye, which at first puzzled me, but when the cause was explained, confirms in no slight degree the accuracy of the methods employed and their fitness to reveal the minutest motion of the glacier. The curves of Plate IX. fig. 2, cut the axis, not all exactly at the same point; but on an average this point may be fixed with tolerable accuracy between the third and fourth mark, or seven feet from the fundamental station Q. *The first and second marks moved evidently slower than the point Q, or the zero*, and the progress of the third and fourth is dubious or irregular. The cause of this peculiarity was clearly ascertained *on the spot* to be the existence of two crevasses belonging to the lateral system of crevasses, between which at their thinning out the station Q had been placed, under the idea that their distance was sufficiently great not to affect the motion. The position of these crevasses is shown in Plate VIII. fig. 3, by which it will be seen that they were fifty feet apart in the direction of the length of the glacier, and that a line joining their extremities passed eight feet nearer the centre of the glacier than the point Q, thus almost coinciding with the point of contrary flexure, which was evidently occasioned by a slightly superior advance of the mass of ice on which Q was placed, thus insulated in some degree between the two fissures. This enables us to transfer the origin of our curve to a point of undoubted solidity, namely, the fourth station, from which point it swells with the regularity which has been described, and which establishes the compactness of the ice experimented on in the most convincing manner.

Thirdly. The curves reckoned from the origin, thus experimentally indicated, show in a beautiful manner the convexity in the direction of the glacier motion before alluded to, which is singularly striking, considering the shortness of the space in which it is developed with nearly mathematical precision, being only about $\frac{1}{25}$th of the breadth of the glacier in this place (see ground plan, Plate VIII. fig. 1.). Even an inspection of the curves (Plate IX. fig. 2) can faintly convey the impression made upon my own mind, when upon the 26th of August I placed the theodolite for the last time over station Q, and caused the vertical wire to pass in front of the line of pins bent into the convex shape by the relative motion of six days' continuance. Thus seen in foreshortened perspective, the eye would in an instant have seized an abrupt motion or discontinuity of the line, but "the appearance of the curve they formed was beautiful; the whole line of pins was deviated from the usual line QQ1 by an angle equal to 12·45 inches, seen at a distance of ninety feet, or about 40′, and besides this, the pins lay in a beautiful and nearly continuous curve, presenting its convexity towards the valley, and decidedly without any great step or start. This was beautifully seen when I directed the vertical wire of the theodolite upon the forty-fifth pin and caused it to describe a vertical plane*. I observed however a curious fact, plainly indicated by the numerical results; the curve crossed the axis at the fourth pin, and attains its greatest convexity at the twenty-fifth†."

Fourthly. That no information might be wanting as to the precise condition of the mass of ice under experiment, I made a very minute examination of the state of the transverse line with respect to the occurrence of *flaws* in the ice. The most important of these was one which returned into itself, crossing the line towards the origin of the glacier between the twenty-sixth and twenty-seventh marks, and returning backwards between the fortieth and forty-first without extending further upwards. Such a flaw, even if devoid of cohesion, could only act by allowing the piece of ice contained between the twenty-seventh and fortieth mark to slip bodily forwards, leaving a vacuity behind. No such slip is recorded in the observations, and no such gap or vacuity was left during the continuance of the observations for seventeen days. Nothing approaching to an open fissure occurred in any part of the space of ice under observation, and the few flaws noted (see the column of remarks in Table IV., and the indications of them by dotted lines and arrows in Plate IX. fig. 2, showing their directions) were perfectly close, and all more or less of zigzag forms, preventing the possibility of sliding. The *veined structure* was developed in every part of the section, in some parts more admirably than others, as near the seventh mark, and between the fortieth and forty-fifth. These countless blue veins may be considered as so many flaws or partial solutions of continuity, existing or having existed; they are almost perfectly *straight*, and (as will be shown immediately) *exactly* in the direction in which the relative motion of the parts of the ice demonstrated by these experiments takes place. It would require strong evidence to convince us that these veins are not occasioned by, and the mechanism of, the plastic motion of the ice.

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* An approximation to this effect will be obtained by stretching a fine thread over the figure.

† From my notes made at the time.

The beautiful convexity of the curves in the direction of motion which the eye at once seized, and could more accurately distinguish by the theodolite, as having its largest sagitta at the twenty-fifth mark, namely, almost exactly midway between the fourth mark or convex origin, and the forty-fifth or extreme mark, contains in itself an evidence with which no person of correct habits of thought can fail to be struck as proving a regular plastic action of gravity or other propelling force acting from point to point on the mass of the glacier. I made however a check experiment almost unnecessary, but which I will here detail. Lest it should be alleged that the whole area under experiment was a moving one capable of being *swung* round by the pressure upon the centre of the glacier, so that the displacement of the transverse line was due to rotation of the mass operated on round some distant centre, I took care near the commencement of my experiment to fix a mark in the ice in the same line with Q parallel to the length of the glacier, or perpendicular to the transverse visual line at the commencement of the experiment. This point is marked q in Plate VIII. fig. 3. Now had the block of ice on which the marks Q, q, (1), (2), (3), &c. were fixed, been revolving round some fixed or moveable centre, the right angle (3) Q q would have remained a right angle, and so for (2) Q q and (1) Q q. But these angles constantly became more obtuse, and that in different degrees depending on the convexity of the curve Q, (1), (2), (3): and so of (4) and (5). It is impossible, therefore, to avoid the conclusion, that the solid ice was itself *distorted* to the amount of the excess of progression of the more central above the lateral stations.

The results are contained in the following Table, the five stations being those formerly mentioned at 30, 60, 90, 120, and 180 feet from Q. The first three stations were fixed when the visual line had an azimuth of 89° 55′ from q; the fourth was fixed on the 14th of August, when the visual line had revolved through 3′ (its daily progression towards q in consequence of the translation of the station Q being 1′ 30″ exactly), and the fifth on the 17th, when the visual line was in azimuth 89° 47½′.

Table V.—Showing the variable azimuths (observed) of the transverse stations with the longitudinal direction Q*q*.

Date.	(1).	(2).	(3).	(4).	(5).	Angle Q1 Q *q*.
	° ′	° ′	° ′	° ′	° ′	° ′
August 12. 2 P.M.	89 55	89 55	89 55	......	......	89 55
14. 1 P.M.	90 6½	90 5	90 5	89 52		
17. Noon.	90 26	90 24	90 23	90 8	89 47½	
19. 5 P.M.	90 47	90 46	90 44	90 10	89 52	
21. 6 P.M.	90 56	90 56	90 53	90 21	90 3	
23. 1 P.M.	91 9½	91 9½	91 4½	90 34	90 14	
26. Noon.	91 24	91 23	91 18	90 45	90 24½	89 28½

In the last column is the observed azimuth of the visual line joining the fixed point Q1 with the moveable station Q, from the mark *q* in the glacier, on the first and last observation. This angle had therefore diminished by 26′½. Now from the known progression of Q, and the known distance QQ1, we computed at page 166 the rotation of the visual line, and found it to be 25′ 54″. This close correspondence is highly satisfactory, as showing that the relative positions of Q and *q* remained unchanged during the continuance of the experiment with reference to the imaginary transverse line by which they were adjusted. It is worthy of notice that the line Q*q* was exactly in the direction of the veined structure.

Edinburgh, July 1845.

XIV. *Illustrations of the Viscous Theory of Glacier Motion.*—Part III.

By James D. Forbes, *Esq., F.R.S.S. L. and E., Corresponding Member of the Institute of France, and Professor of Natural Philosophy in the University of Edinburgh.*

Received January 27,—Read February 26, 1846.

§ 6. *On the Motion of Glaciers of the Second Order.*
§ 7. *On the Annual Motion of Glaciers, and on the Influence of Seasons.*
§ 8. *Summary of the Evidence adduced in favour of the Theory.*

§ 6. *On the Motion of Glaciers of the Second Order.*

Up to the year 1844 no attempt had been made, so far as I am aware, to measure the rate of motion of those comparatively small isolated glacial masses reposing in the cavities of high mountains, or on *cols*, called by De Saussure *Glaciers of the Second Order.*

Some observations had indeed been made upon a glacier of this description in 1841, and by MM. Martins and Bravais, during a residence on the Faulhorn. But it was not at that time known that the motion of glaciers was a continuous and regular one, admitting of rigorous measurement even in short intervals of time, and the importance of such observations was overlooked. They accordingly believed that the glacier in question had no sensible motion, and probably they did not attempt to observe it until a subsequent year. It is impossible now to doubt that the *Blau Gletscher*, near the Faulhorn, has a movement like all other bodies of the kind.

In July 1844, I had an opportunity of passing some days at the hospice of the Simplon, in the neighbourhood of which exists a small glacier of the second order, easy of access, and very fit for the experiment which I proposed to myself upon such bodies. Its diminutive size made it all the more suitable; for should it be found to possess a regular motion, we are certain that the *mechanism of a glacier* is continued within the small compass of a mass which may be conveniently examined in detail in all its parts. It is lodged in a niche of the mountain called the Schönhorn*, immediately behind the Simplon hospice: we shall therefore call it the glacier of the Schönhorn. From its inconsiderable extent, it might easily be overlooked by a passing traveller amidst the multitude of vast and striking objects by which he is surrounded†. It is perched, as has been said, in a kind of niche on the northern face of the Schönhorn, somewhat about an hour's steep climb above the hospice; consequently about 1400 feet higher. The hospice is itself 6580 English feet above the level of the sea; the mean height of the Schönhorn glacier may be taken at 8000 feet. I had not an opportunity of ascertaining it more accurately.

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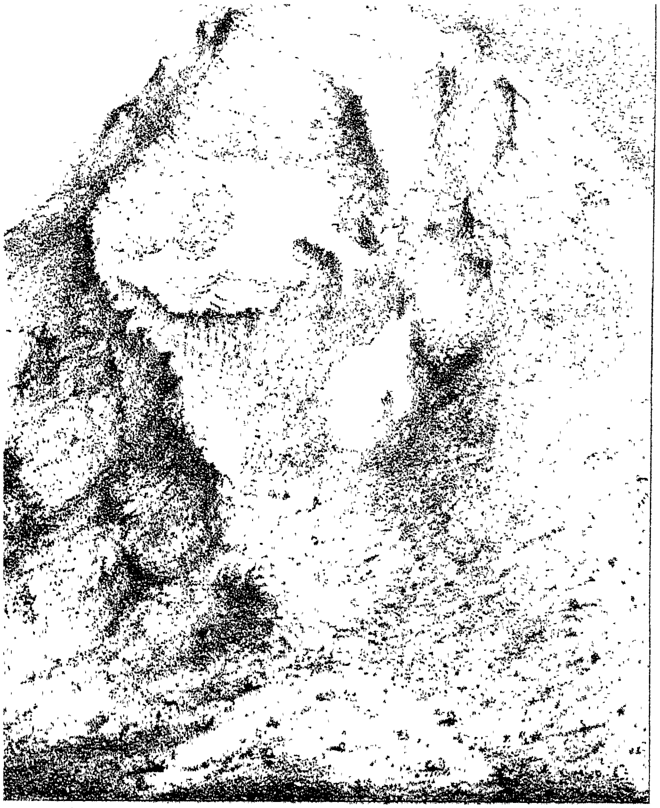
* Also called Hübschhorn, an equivalent epithet.

† The reader will not for a moment imagine that it is the Kaltwasser glacier of which we speak, which lies also in the neighbourhood of the Schönhorn, descending from the Monte Leone and Wasenhorn, and from which the *Galerie du Glacier* on the Simplon road takes its name.

Plate X. figs. 1 and 2, shows a sketch of a front view of the Schönhorn taken from the opposite heights, and a ground plan of the glacier. The latter is sketched merely by the eye, but the scale is furnished by some actual measures. I first visited the glacier on the 20th of July 1844. It was then covered over, by far the greater part of its extent, with snow, as shown in the plan. This snow is in great part manifestly permanent, and the glacier is therefore in the state of *névé*. The general slope is from top to bottom of the plan, and its inclination is variable, depending upon the direction of the avalanches by which it is fed, of which the principal descends the rapid *couloir* marked C, when the inclination is about 35°. This avalanche forms a sort of ridge down the glacier, as indicated by the shading of the map, leaving a considerable space comparatively flat to the eastward. On the west, the snow thins off from the ridge until it exposes the ice near the part marked B, where the slope is still considerable, being 20°, and here we have the real mass of the glacier exposed, although the ice is not of an exceedingly hard or crystalline character. The front or lower termination of the glacier all along presents a steep, nearly precipitous surface of ice, sloping from 45° to 60°. This ice rests on a bed of debris of rock which appears to be inclined about 25°. Except near the precipitous termination of the glacier, there are no apparent crevasses. The surface is uniform and uninterrupted. Some water issues from beneath the steepest part of the ice; but even in the middle of the day, near the end of July, there was exceedingly little. The length, if it may be so termed, of the glacier, from back to front is about 1000 feet, and its greatest breadth 1300 feet. Its surface may be roughly estimated at twenty-six acres.

The rock of which the Schönhorn is composed, is an alternation of the slaty rocks resembling gneiss with talc slate, which are so common in this part of the Alps. To my great surprise, on one of my visits, I heard the sound of hammers and blasting in this elevated and remote spot; and found two men employed in quarrying Potstone (*Lapis ollaris*) for building ovens, from a retired nook beyond the glacier; the quarry is marked on the plan at E.

On the 20th of July 1844, I ascended to the glacier, accompanied by M. Alt, one of the clerical members of the Simplon establishment, and an assistant; and I fixed upon a position, marked St. on the rock on the east side of the glacier, for planting the instrument, which was then directed, as nearly as I could judge, in a line transverse to the prevailing slope of the glacier, and the telescope was made to describe a vertical plane. It was then sighted upon a well-marked quartz vein on the rock on the distant side of the glacier, marked D, by which it could at any time be brought into precisely the same position; the position of the instrument itself being



View of the Glacier at the Schonhorn-Simplon.

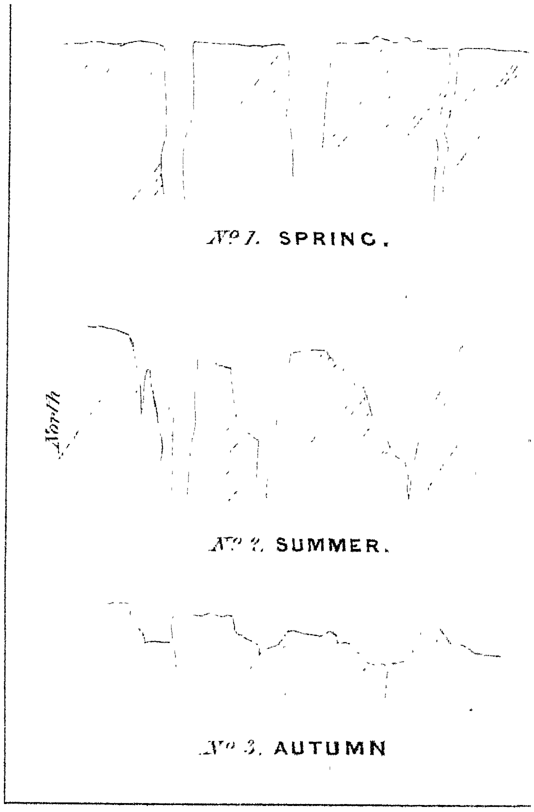
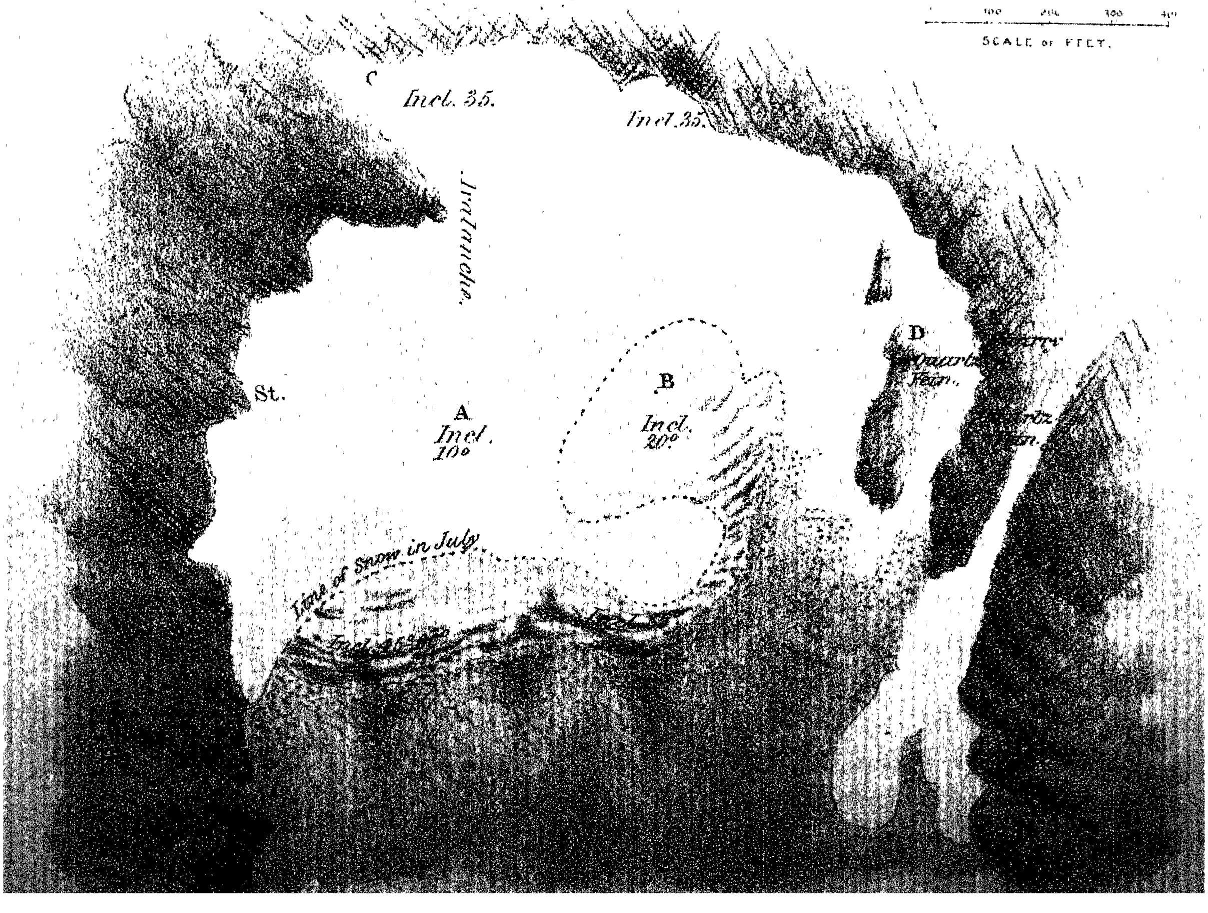


Fig. 2. p.178.



referred to a mark cut on the rock where it stood. Two marks were then fixed on the glacier; one was a pole stuck in at A, several feet into the snow of the avalanche already described as traversing the length of the glacier. The slope of the snow at the point A was about 10°; and the distance of A from the station St., by an approximate measurement, 340 feet. 350 feet further in the same direction, a hole was made with a blasting iron into the solid ice at B, where the inclination was 20°. The precise position of these marks being determined relatively to the visual line, the observation was finished at 4 o'clock P.M.

On the 23rd of July we returned. The mark A in the snow (which was so firmly driven in that it could not be withdrawn without breaking the pole) had advanced in the direction of the slope exactly four inches at 1 P.M., or in sixty-nine hours; whilst the mark B in the ice had advanced $5\frac{1}{4}$ inches in the same time; whence we have

Velocity of A in twenty-four hours	1·4 inch.
Velocity of B in twenty-four hours	1·8 inch.

The result was what I had anticipated, although it must be confessed it might be expected to be nearly the same upon any theory of glacier motion yet proposed. The slope of a glacier, *per se*, is not an index of what should be the velocity of motion on the viscous theory. No doubt, other things being equal, the velocity will be proportional to some function of the declivity, and such we have seen to be fully borne out by experiments on the Mer de Glace of Chamouni; and in the present case, the velocity under a slope of 20° was about one-third greater than that under a slope of 10°. But the analogy of a river, as well as theoretical considerations, show that the slope is but one of numerous considerations; such as (1) the *mass* of the viscous body; the smaller the mass the smaller the velocity on a given slope*; (2) the state of infiltration or wetness of the glacier altering its resistance to change of form†. Without mentioning other causes, these are quite sufficient to account for the small velocity observed, when we recollect the very insignificant mass of this glacier and its dry state arising from its great elevation, its northern exposure, and even the very inclination of its bed which keeps it in a state of perfect drainage and leaves it always in a state tending to the *snowy*, rather than that of imbibition.

§ 7. *On the Annual Motion of Glaciers, and on the Influence of Seasons.*

The first estimate of the least authority on the advance of any point of a glacier rom year to year, was made by Hugi on the glacier of the Aar, from 1827 to 1836. The method employed was to measure the distance of a well-marked block of stone, esting on the ice from a transverse line determined by the fixed objects on the shore. This is the only way, generally speaking, practicable upon glaciers at a distance rom habitations, and where marks cannot be conveniently renewed in the ice from ime to time during the whole year. The velocity of the part of the glacier immediately below the promontory, called the Abschwung, was found to be about 240 feet per annum, which though neither confirmed nor invalidated by the discordant measurements subsequently made by other observers on the same glacier, has at length been substantially corroborated by a professional surveyor, M. Wild, who has recently undertaken the verification at M. Agassiz's request.

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* Travels in the Alps of Savoy, 2nd edit., p. 387.

† Ibid. pp. 148, 371.

After having myself observed the motion of several points of the Mer de Glace of Chamouni during the summer of 1842, I fixed the positions of two conspicuous blocks, one near Montanvert, marked D 7; and another opposite the Tacul, marked C, or the Pierre Platte (see my Map of the Mer de Glace), by means of which I hoped to ascertain the mean annual motion in succeeding years. With respect to the latter, or the Pierre Platte, I was successful; for in September 1843 I ascertained geometrically its change of position, subject however to the uncertainty of a few yards, owing to the sliding of the block from the pedestal of ice upon which it was so picturesquely poised*, a circumstance which happens once or twice in the course of every summer.

From the 17th of September 1842, to the 12th of September 1843, the advance was (in 360 days)	256·8 feet.
Or reduced to the exact year of 365 days	260·4 feet.
Mean daily motion	8·56 inches.

Again, being enabled to repeat the measures in 1844, I found the advance—

From the 12th of September 1843, to the 19th of August 1844 (342 days)	270 feet.
Proportional motion for 365 days	288·3 feet.
Mean daily motion	9·47 inches.

In the case of the block D 7, I was less fortunate. It was very near the western side of the glacier, and though not thrown up on the shore, yet the ice on which it rested got in some manner so embayed or entangled, that though its motion had been steadily watched during the winter of 1842–43 by my able assistant, Auguste Balmat, it had scarcely moved since his last observation on the 8th of June 1843, when I visited it in September of the same year. It must be presumed that it had been much retarded previously, and hence it is clearly inadmissible to infer a proportional motion for the portion of the year when it had not been observed, as I did in the Postscript at the end of the first edition of my Travels, whilst in ignorance of the then unsuspected retardation. The motion actually observed was 432 feet in 322 days, being at the rate of 483 feet per annum, or 15·88 inches per day. This is therefore undoubtedly *below* the true measure of the annual motion of the side-part of the glacier somewhat in advance of the Châlet of Montanvert (see the position of D 7 in the Map). It may at least be of some service as an *inferior limit* of the annual motion there.

In 1843 I fixed approximately the position of a block marked P, higher up the glacier than the Montanvert, and near its left bank, exactly opposite the spot called Les Ponts.

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* See Frontispiece to Travels through the Alps of Savoy.

The observation, being repeated the ensuing year, gave a motion of *about* 486 feet (the nature of the observation did not admit of the same accuracy as at station C) from the 13th of September 1843 to the 9th of August 1844, or 331 days, being at the rate of

536 feet per annum,
or 17·62 inches per day.

In 1844 I made the casual discovery of one of my staves, used to mark the position of the station A at the *Angle*, a little higher up the glacier than the last, a point of which the motion had been most carefully observed during the summer of 1842 (see Travels, p. 140). This stick still bore legibly written upon it the date when it had been fixed in the ice at station A, and as the painted marks on the rock of the *Angle* were still as fresh as when they were made, I had no difficulty in finding the exact position on the glacier which this mark had in any part of the summer of 1842, and by measuring the distance to the place where it was found (which was on a spot of the ice quite unfrequented by guides or any one else), I had good reason for believing that this must be the space over which it had travelled in the mean time; although of course I do not ascribe to this observation the weight of a direct measure, yet it proves an interesting confirmation. Reckoning from the position it occupied on the 1st of September 1842, it had advanced down to the 26th of August 1844,

or in 720 days . . . . 952 feet,
or, per annum . . . . 482·5 feet.
Mean daily motion . . . 15·87 inches.

It will be seen that this result is in close agreement with that observed at station P above mentioned, which is a little further down the glacier, but about the same distance from the side; for though the motion of P is somewhat greater for 1843–44 than the mean motion of A for 1842–44, it will be seen by the comparative observations at C already referred to, that the glacier moved more rapidly in 1843–44 than in 1842–43.

But I am now enabled to present a view of the actual progress of two glaciers during every part of the year from direct observation. For these I am indebted to the intelligent and persevering zeal of my excellent guide and assistant at Chamouni, AUGUSTE BALMAT, of whose character I have had the pleasure of forming a more and more favourable estimate the longer I have been acquainted with him. To the long training of the laborious summer of 1842, when he assisted me, he adds the further experience derived from my visits in 1843 and 1844, in the latter of which especially he became familiar with the nice precautions requisite in conducting the most accurate measurements, and received instructions from me which rendered him perfectly competent to continue by himself the simpler kind of measurements which I have alone required of him. The extraordinary exertions which he used to obtain the winter motion of the block D 7, under the Montanvert, in 1842–43, have been noticed in my former publications. On one or two occasions, as I learned afterwards from himself, being unable to ascend the usual path to the Montanvert for fear of spring avalanches, he actually clambered with a companion up the rugged ascent from the source of the Arveiron, plunging continually up to the middle in snow, for no other purpose than to make the observation which I had requested of him; and it would be unjust not to mention at the same time the admirable, because rare, generosity, with which he positively refused for himself any share of the remuneration which I pressed upon him the following summer, as some recompense for the fatigues and dangers which he had braved to obtain for me this information. With such a person, my confidence in the observations which he has since made at points much more accessible, and with the experience of some additional years, is complete. I do not mean that mistakes may not occur, or even that the measures may not be less exact than I might have taken myself; but from my knowledge of the man, I am nearly as confident in their *being faithfully reported, exactly as they were made*, as if I had done so myself.

With a view to lighten the labour as much as possible, I selected two stations on the *glacier of Bossons*, and desired Balmat to select two on the *Glacier des Bois* (the outlet of the *Mer de Glace* towards the valley of Chamouni); all these points being tolerably accessible at every season of the year.

The general method of observation was the following:—vertical holes were driven into the ice with a 4-foot blasting iron, at the points whose motion was to be determined; and these holes were renewed from time to time as the surface of the ice wasted. A staff of wood 5½ feet long, was stuck in each, which projected sufficiently above the snow (which never appears to have exceeded 2½ feet deep on the glacier) to make it visible at all seasons. During winter the staves were frozen into the ice, and the waste being small, the holes did not require renewal. Two marks are then made of a permanent kind on the rocks of the moraine, or two staves driven in, or a distant object on the farther side of the glacier was observed, so as to mark out sufficiently a line transverse to the glacier, the prolongation of which passes over the hole in the ice when first made; and the advance of the hole in the ice beyond this fixed visual line marks the progress of the glacier. The want of a theodolite is supplied by directing the eye past a plumb-line suspended over the fixed mark on the moraine nearest to the glacier, the eye of the observer being over the farthest mark. As the spaces moved over were in most cases considerable, an error of a few inches, or even a foot, is not important to the result. The progress was in every case determined by means of a line marked with *English* feet and inches, left by me at Chamouni on purpose.

The results were communicated to me regularly by letter at intervals of a few weeks during the whole year, and all questions asked and explanations required by me were answered by return of post.

Those who may look with suspicion upon observations made in a remote place by a peasant of the better class, though they may not partake of my security in the results from knowing the character of the individual, will, I believe, have their doubts removed by the internal evidence of this important series of observations, which even a philosopher could not have invented, and which, it will be seen, are confirmed by data of quite another kind over which the observer could have no control, I mean the Meteorological Registers of Geneva and St. Bernard.

Table I.

First Station on the Glacier des Bois, a little way below the Chapeau, and at about *one-third* of the breadth of the glacier from its eastern bank.

						Space moved over in English feet and inches.		Daily motion.
From 1844			To 1844.			feet.	inches.	inches.
October	2.	10 A.M.	October	14.	9 A.M.	32	0	32·0
October	14.	9 A.M.	November	2.	8 A.M.	43	11	27·8
November	2.	8 A.M.	November	19.	4 P.M.*	34	11	24·2
November	20.	1 P.M.	December	4.	3 P.M.	13	10	11·8
			1845.					
December	4.	3 P.M.	January	7.	3 P.M.	32	8	11·5
1845.								
January	7.	3 P.M.	February	18.	3 P.M.	49	2	14·0
February	18.	3 P.M.	March	18.	2 P.M.	39	10	17·0
March	18.	2 P.M.	April	17.	10 A.M.	42	1	16·9
April	17.	10 A.M.	May	17.	8 A.M.	56	3	22·5
May	17.	8 A.M.	May	31.	2 P.M.	43	11	37·0
May	31.	2 P.M.	June	19.	4 P.M.	61	11	38·4
June	19.	4 P.M.	July	4.	10 A.M.	52	0	42·3
July	4.	10 A.M.	July	18.	5 P.M.	62	0	52·1
July	18.	5 P.M.	August	6.	4 P.M.	77	6	49·0
August	6.	4 P.M.	October	8.	4 P.M.	187	8	35·7
October	6.	9 A.M. (?)	November	8.	2 P.M.	100	9	36·4
November	8.	2 P.M.	November	21.	1 P.M.	32	6	30·1

Table II.

Second Station, Glacier des Bois, near the lowest extremity, just behind the "Côte du Piget."

						Space moved over in English feet and inches.		Daily motion.
From 1844			To 1845.			feet.	inches.	inches.
December	4.	2 P.M.	January	7.	4 P.M.	8	6	3·3
1845.								
January	7.	4 P.M.	February	18.	4 P.M.	8	11	2·6
February	18.	4 P.M.	March	18.	3 P.M.	7	0	3·0
March	18.	3 P.M.	April	17.	11 A.M.	11	7	4·6
April	17.	11 A.M.	May	17.	9 A.M.	18	4	7·3
May	17.	9 A.M.	May	31.	1 P.M.	10	5	8·8
May	31.	1 P.M.	June	19.	2 P.M.	13	3	8·3
June	19.	2 P.M.	July	4.	9 A.M.	14	1	11·1
July	4.	9 A.M.	July	18.	6 P.M.	17	6	14·6
July	18.	6 P.M.	August	6.	3 P.M.	18	8	11·9
August	6.	3 P.M.	October	6.	7 A.M.	50	1	9·9
October	6.	7 A.M.	November	8.	4 P.M.	27	2	9·8
November	8.	4 P.M.	November	21.	11 A.M.	8	0	7·5

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* There is some uncertainty about the circumstances of this observation, which from the difficulty of corresponding satisfactorily at so great a distance about minute local occurrences, I have been unable perfectly to clear up. It is probably correct as it stands.

TABLE III.

First Station on the Glacier des Bossons. Some way above the Plateau, where the glacier is usually crossed; on the west side, and near the moraine.

						Space moved over in English feet and inches.		Daily motion.
From 1844			To 1844.			feet.	inches.	inches.
November	20.	Noon.	December	4.	3 P.M.	20	4	17·3
			1845.					
December	4.	3 P.M.	January	7.	1 P.M.	44	11	15·9
January	7.	1 P.M.	February	14.	4 P.M.	46	9	13·6
February	17.	4 P.M.	March	17.	Noon.	35	10	15·4
March	17.	Noon.	April	16.	5 P.M.	32	7	12·9
April	16.	5 P.M.	May	17.	3 P.M.	60	0	23·3
May	17.	3 P.M.	May	31.	8 A.M.	49	0	42·9
May	31.	8 A.M.	June	19.	10 A.M.	54	2	34·1
June	19.	10 A.M.	July	4.	5 P.M.	53	8	42·1
July	4.	5 P.M.	July	21.	2 P.M.	43	1	30·6
July	21.	2 P.M.	August	7.	3 P.M.	40	10	28·8
August	7.	3 P.M.	October	6.	Noon.	103	0	20·6
October	6.	Noon.	November	10.	2 P.M.	56	8	19·4
November	10.	2 P.M.	November	22.	11 A.M.	22	5	22·6

TABLE IV.

Second Station on the Glacier des Bossons. Near the lowest extremity of the glacier, where free from the moraine, on the western side.

						Space moved over in English feet and inches.		Daily motion.
From 1844			To 1844.			feet.	inches.	inches.
October	2.	2 P.M.	October	13.	4 P.M.	12	11	14·0
October	13.	4 P.M.	October	31.	10 A.M.	25	1	17·0
November	20.	1 P.M.	December	4.	2 P.M.	15	4	13·1
			1845.					
December	4.	2 P.M.	January	7.	3 P.M.	36	11	13·0
1845.								
January	7.	3 P.M.	February	19.	1 P.M.	43	1	12·0
February	19.	1 P.M.	March	17.	1 P.M.	27	10	12·8
March	17.	1 P.M.	April	16.	6 P.M.	25	8	10·2
April	16.	6 P.M.	May	17.	4 P.M.	49	11	19·4
May	17.	4 P.M.	May	31.	9 A.M.	34	6	30·2
May	31.	9 A.M.	June	19.	11 A.M.	44	2	27·8
June	19.	11 A.M.	July	4.	6 P.M.	41	2	32·3
July	4.	6 P.M.	July	21.	11 A.M.	37	3	26·4
July	21.	11 A.M.*	August	7.	4 P.M.	30	3	21·4
August	7.	4 P.M.	October	6.	2 P.M.	82	7	16·5
October	6.	2 P.M.	November	10.	4 P.M.	17	3	5·9
November	10.	4 P.M.	November	22.	1 P.M.	7	2	7·2

These four sets of observations are projected in Plate XI. fig. 1, where the four lower zigzag curves represent the gradation of diurnal velocity by periods, according to the method adopted in projecting my own observations in my Travels, p. 141. The general accordance is sufficiently manifest, and the effect of the season of the year is beautifully shown, the following being the minimum and maximum values:—

	Daily motion in inches.
Glacier des Bois, No. I., minimum in December	11·5
Glacier des Bois, No. I., maximum in July	52·1
Ratio of maximum to minimum	4½ : 1
Glacier des Bois, No. II., minimum in January	2·6
Glacier des Bois, No. II., maximum in July	14·6
Ratio of maximum to minimum	5½ : 1
Glacier des Bossons, No. I., minimum in March	12·9
Glacier des Bossons, No. I., maximum in May	42·9
Ratio of maximum to minimum	3½ : 1
Glacier des Bossons, No. II., minimum in March	10·2
Glacier des Bossons, No. II., maximum in June	32·3
Ratio of maximum to minimum	3¼ : 1

From these observations we may deduce the annual motion from November 1844 to November 1845 with considerable exactness. Allowing for the fractional parts of a year, we obtain the following results, amongst which I have included a separate computation of the mean daily motion for the summer period (April—October), and the winter period (October—April).

TABLE V.

	Bois, No. I.	Bois, No. II.	Bossons, No. I.	Bossons, No. II.
	feet.	feet.	feet.	feet.
Motion for 365 days, November 1844 to November 1845....	847·5	220·8	657·8	489·1
	inches.	inches.	inches.	inches.
Mean daily motion	27·8	7·3	21·6	16·1
Mean daily motion, summer period, April to October	37·7	9·9	28·0	22·2
Mean daily motion, winter period, October to April	19·1	4·7	15·8	10·7
Ratio, summer: winter, motion..........................	2·0 : 1	2·1 : 1	1·8 : 1	2·1 : 1

I. From this Table we deduce in the first place a mean annual motion far greater than has hitherto been observed, or perhaps suspected in any glacier, that of near 300 yards, or almost *one sixth* of a mile. This is on the Glacier des Bois beneath the *Chapeau*, where the inclination of the glacier is very steep, adding a new illustration of the general principle*, that in *similar* circumstances the velocity increases with the slope. To this cause may be added the high temperature of the air of the valley to which in this part of its course it is exposed; but this last cause is alone insufficient; for

II. We find that the lowest part of the same glacier immediately behind the Côte

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Travels, 2nd edit. p. 371.

du Piget, a little way above the source of the Arveiron, and therefore still deeper in the valley, has a mean velocity nearly *four times less*, arising solely from the diminished slope and volume of the glacier in that part*. Hence there must be a condensation of the ice here, a pressure *à tergo*, the quicker moving ice pressing against the slower, consolidating it, remoulding its plastic material and sealing the crevasses; and a slight examination of the state of the glacier at the points in question will show this to be the case.

III. All that has now been said with respect to the two stations on the Glacier des Bois may be repeated with only numerical differences with respect to the two stations on the Glacier des Bossons; the one set of observations confirming the other.

IV. In both glaciers the summer motion exceeds the winter motion in a greater proportion, as the station is lower, that is, exposed to more violent alternations of heat and cold; this we shall find to be general.

Before continuing our deductions, we would call attention to the close relation which may be established between the mean temperature of any portion of the year and the velocity of the glacier corresponding to it. This is done in figure 1, Plate XI., exactly in the same way as I did when comparing my observations in the summer of 1842 with the corresponding changes of temperature†. That is to say, I have projected by *periods* (corresponding to the intervals of observation on the glaciers) the mean temperatures as observed at Geneva and at the Great St. Bernard, which are regularly published in the *Bibliothèque Universelle*, the average of which (separately deduced from the mean of daily maxima and minima, and projected in the upper part of the figure) may represent not inaptly the average temperature to which the glaciers in question, and especially the middle and lower regions of them, are exposed; and further, this average possesses the advantage of being derived from data wholly unconnected with the place or parties where and by whom the observations on the motion of the glaciers were made, and therefore are free from the remotest suspicion of either in any degree influencing the other.

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* This explains a circumstance which has always hitherto been a difficulty to me; the united testimony of the best-informed inhabitants, not only at Chamouni but elsewhere (as at Zermatt and at the Simplon), to the effect that during winter the lowest end of a glacier, which terminates in a valley, does not greatly protrude, nor force the snow before it. This arises in fact from the comparative smallness of the motion which the *tongue* of such a glacier appears to possess, especially in winter.

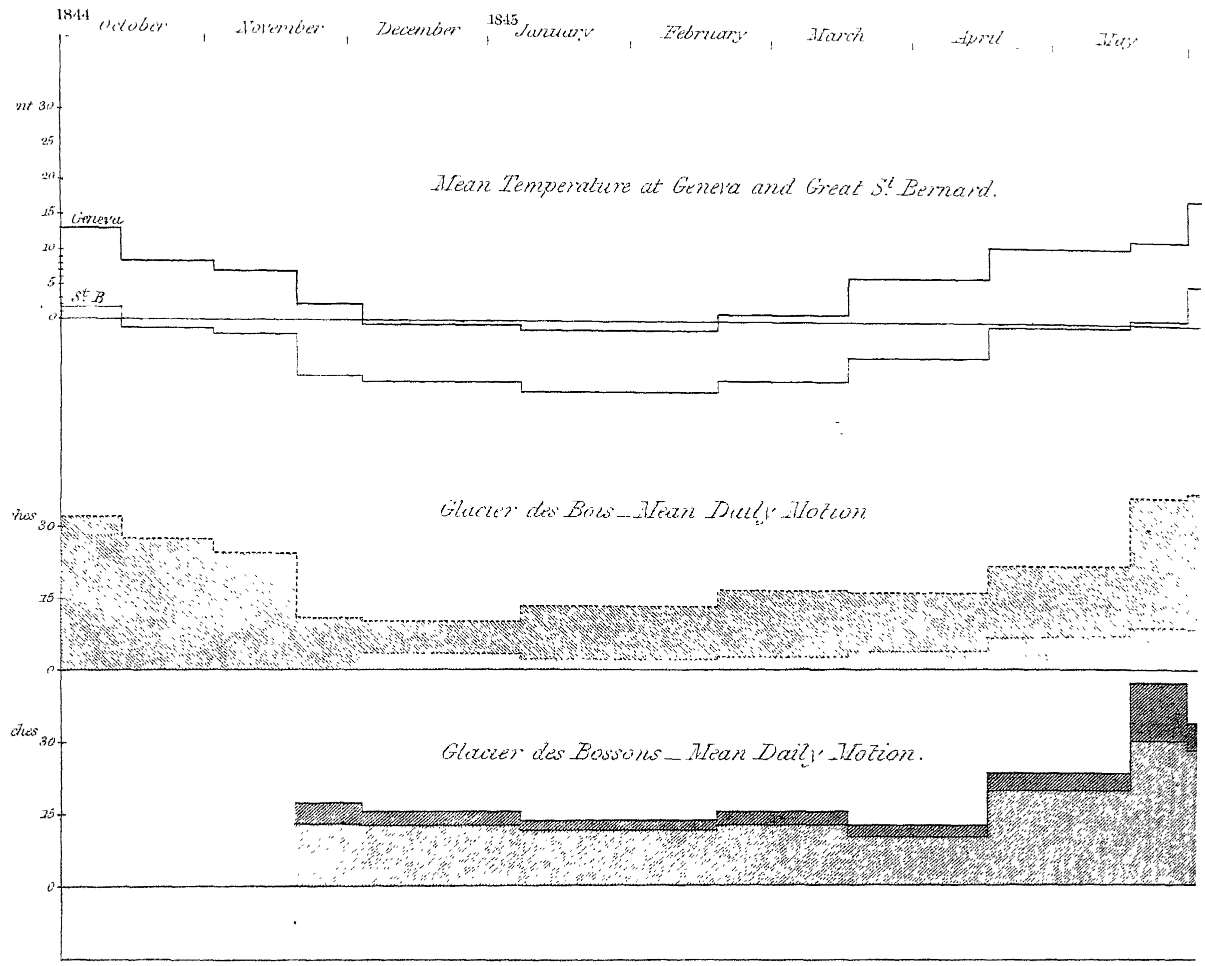
1844
October
November
December
1845
January
February
March
April
May
nt 30
25
20
15
10
5
0
Mean Temperature at Geneva and Great St Bernard.
Geneva
St B
hes 30
15
0
Glacier des Bois _ Mean Daily Motion
ches 30
25
0
Glacier des Bossons _ Mean Daily Motion.

FIG. 2. p. 191.

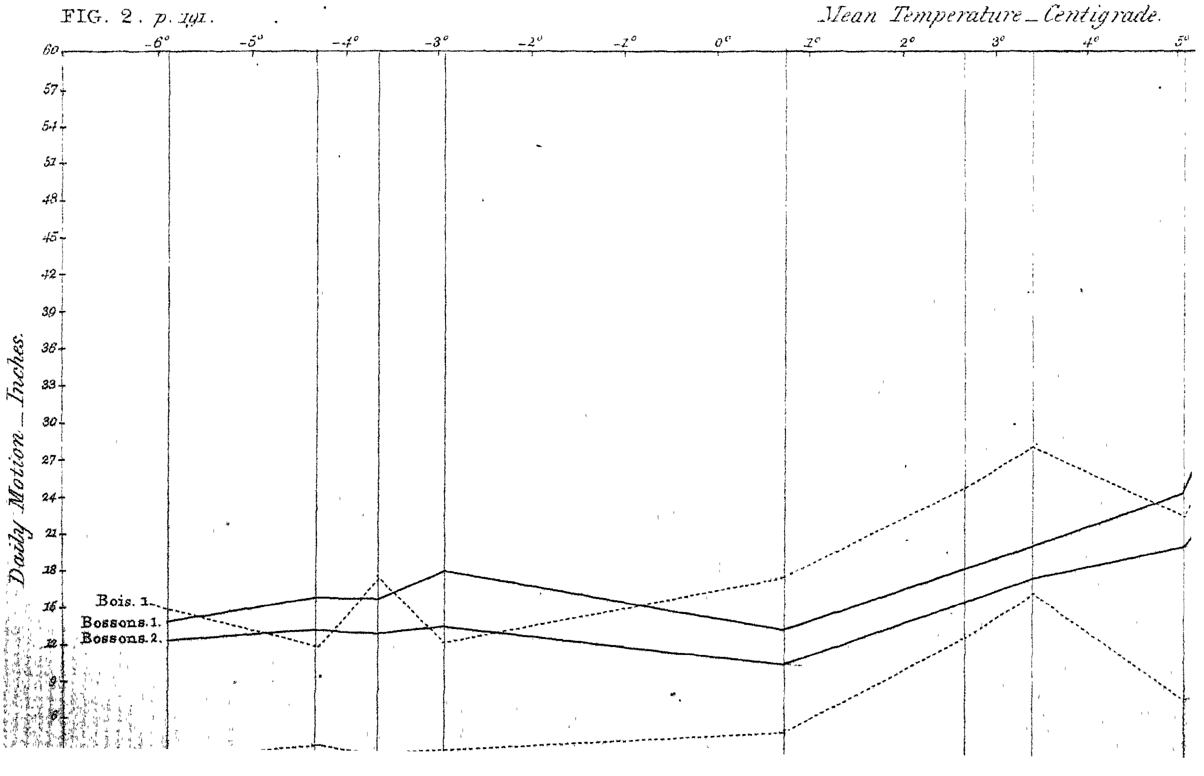
Mean Temperature _ Centigrade.
-6°
-5°
-4°
-3°
-2°
-1°
0°
1°
2°
3°
4°
5°
60
57
54
51
48
45
42
39
36
33
30
27
24
21
18
15
12
9
6
Daily Motion _ Inches.
Bois. 1.
Bossons. 1.
Bossons. 2.

TABLE VI.

Mean Temperatures (by periods) on the Centigrade Scale, observed at Geneva and the Great St. Bernard*.

	Geneva.		St. Bernard.		Means of Max. and Min.	
	Max.	Min.	Max.	Min.	Geneva.	St. Bernard.
1844. Oct. 2 to Oct. 14. ..	17·37	8·57	4·16	– 1·58	12·97	1·29
Oct. 14 to Nov. 2. ..	11·77	5·13	1·61	– 4·93	8·45	– 1·66
Nov. 2 to Nov. 19. ..	11·84	3·11	1·62	– 5·66	7·47	– 2·02
Nov. 19 to Dec. 4. ..	4·93	– 0·18	– 5·11	–11·25	2·27	– 8·18
Dec. 4 to Jan. 7.....	1·45	– 2·40	– 5·70	–10·96	– 0·27	– 8·33
1845. Jan. 7 to Feb. 18. ..	1·47	– 4·11	– 6·92	–13·86	– 1·32	–10·39
Feb. 18 to March 18.	4·76	– 2·74	– 3·93	–12·56	1·01	– 8·24
March 18 to April 17.	11·27	1·57	0·19	–10·13	6·42	– 4·97
April 17 to May 17.	16·04	5·56	5·15	– 6·36	10·80	– 0·60
May 17 to May 31...	16·83	6·91	6·04	– 4·67	11·87	0·68
May 31 to June 19...	23·70	12·71	11·48	1·11	18·20	6·29
June 19 to July 4...	22·58	12·13	9·81	0·53	17·35	5·17
July 4 to July 18. ..	24·01	12·84	10·20	2·08	18·42	6·14
July 18 to Aug. 6...	23·28	13·20	9·25	1·68	18·24	5·46
Aug. 6 to Oct. 8.....	21·15	11·31	7·57	0·10	16·23	3·83
Oct. 8 to Nov. 8.....	11·84	3·78	2·38	– 3·70	7·81	– 0·60
Nov. 8 to Nov. 21...	12·54	5·86	– 1·03	– 6·06	9·20	– 3·54

A general comparison of the curves of temperature and those of glacier motion (more particularly on the Glacier des Bois) affords a proof of the justness of the principle laid down by me in 1842, that the motion of the ice "is more rapid in summer than in winter, in hot than in cold weather, and especially more rapid after rain, and less rapid in sudden frosts†;" the evidence of the connection is plainer by mere inspection than any detail could make it. But I request attention to the apparent anomalies of the curves, as affording a stronger evidence of the fidelity with which the measurements have been made, and to the truth of the plastic theory, than perhaps even the general coincidence just referred to.

If the velocity of the glacier depend upon the completeness of its infiltration with water, rendering the whole an imbibed porous mass like a sponge, it cannot depend solely on the mean temperature of any period, but also upon the *wetness* of the surface, whether derived from mild rain, from thawing snow, or from any other meteorological accident which the register of the thermometer cannot of itself indicate‡. Further, a thick coating of snow on the glacier must defend it from the excessive cold of winter just as it defends the earth and plants, and consequently the minimum of motion will not necessarily coincide with the minimum of temperature. Now to stimate these more irregular causes is not so easy; but some light is thrown upon hem by a register of the weather and state of the snow, voluntarily kept for me t Chamouni by Auguste Balmat; which forms a valuable supplement to the thermometrical register of Geneva and St. Bernard. Although the daily details would take up too much space, I will endeavour to give a faithful abstract of them so far as to give a general idea of the climate of Chamouni from October 1844 to November 1845. This diary includes (at my request) occasional notes on the state of the source of the Arveiron, which are of considerable interest.

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* The last three lines have been added during printing.

† Fourth Letter on Glaciers, Edinburgh Philosophical Journal, Jan. 1843; and Appendix to Travels, 2nd edit. p. 415.

‡ "The *proportion* of velocity does not follow the *proportion* of heat, because any cause, such as the melting of a coating of snow by a sudden thaw, as in the end of September 1842, produces the same effect as a great heat would do."—Travels. 2nd edit., p. 372.

Weather at Chamouni.

1844. *October.*—A good deal of rain during the month, which on the 10th and 16th fell as snow on the hills (nine inches at Montanvert), and subsequently to the latter day the glacier at the Montanvert was not clear of snow during the winter. 14th. Source of the Arveiron diminished to *one-fourth* (of the summer volume). Ice-vault more than half closed.

November.—Till 14th much rain and snow; fine with frost after. 20th. Source of the Arveiron very low; has not shifted its usual position.

December.—Weather generally fine throughout; cold most severe from 7th to 12th.

1845. *January.*—The weather continued splendid till the 20th; greatest cold from −2° to −5° Reaumur. 19th. The vault has disappeared at the source of the Arveiron. 20th. The first snow fell which lay at Chamouni, and continued from this day, attaining a depth of 1½ foot in February. Up to this time all the secondary heights, even the Breven and Flegère, were clear of snow, and the weather suitable for Chamois hunting. Occasional snow till the end of the month.

February.—Snow at intervals all the month. 13th. Greatest cold of the season; thermometer −15°Reaum. followed by fine weather. 20th. Snow lies 2½ feet deep at the upper stations on the glaciers; 1½ foot at Chamouni. The arch of the source of the Arveiron has wholly disappeared, but the water issues at the usual places as in summer. The water is reduced to a small amount and may easily be stepped across. It is *still whitish and dirty*, though less so than in summer; *except* when a change of weather is threatened (when it is as dirty as in summer)*. *Same date.* The glacier of Bossons has extended itself much. "On ne s'y reconnait presque plus." It is advancing towards the moraine of 1818; and the lower end is at least seventy feet high.

March 1st—3rd, mild, with rain; 3rd—13th, cold; 15th, *heavy rain.* Alternate rain and fine till end of the month. 27th. Not half a foot of snow lying at Chamouni. The source of the Arveiron has not opened a vault. The quantity and muddiness of the water the same as at the last report.

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* This important remark proves that in the middle of winter a temporary rise of temperature of the air over the higher glacier regions (which is the precursor of bad weather) not only produces a thaw there, but finds

April.—First week fine; second week cold with snow; changeable to the end of the month. 16th. Source of Arveiron has not much increased in water since the middle of March. In the end of April the snow first disappeared from the lower part of both glaciers.

May.—The first half of the month fine, with occasional snow; the second half changeable, with rain. 17th. The source of the Arveiron has increased three-fourths (*means probably in the ratio of four to one*) since the middle of April, and is dirty. The ice-vault is not yet formed. 26th. The Glacier des Bossons advances rapidly and is crumbling into pyramids. The end of the glacier is at least eighty-five feet high and advances considerably, particularly during the month of May; and widens greatly.

June.—A changeable and wet month; a very late season*. The snow did not entirely disappear from the Mer de Glace opposite the Montanvert till the beginning of July. 6th—7th. The vault opened at the source of the Arveiron. The quantity of water since the end of May is the usual summer supply.

July.—Commenced with warm weather. 5th. Thermometer 27° REAUM. The snow has disappeared from the ice opposite Montanvert, but some patches remain on the way to the Jardin. The Mer de Glace is much higher in level (about forty feet) than in former years, and the marks made in the rock at the *Angle* (in 1842) are all covered. The crevasses much the same as usual. The glacier of Bossons has also increased greatly, and appears to be approaching its old moraines. The register for the greater part of July has not come to hand.

August.—A very changeable rainy month. 8th or 9th. The arch at the source of the Arveiron fell in, and did not form again during the season.

September.—Also a changeable month. Rain twelve days.

October.—A very fine month. No rain mentioned after the 7th.

A careful examination of this interesting register will explain several of the apparently irregular inflections of the curves of glacier motion. Thus (to continue our general remarks, p. 186) we find

V. At the upper station on the Glacier des Bois the least velocity occurred in December, whilst at the lower station (and at both of those on the Bossons) a minimum coinciding also with that of the temperature of the air took place in January. This coincides with the important fact noted in the preceding register, that the upper part of the Mer de Glace was covered with snow from the 16th of October, which only lay in the valley of Chamouni from the 20th of January; the snow screening the ice from the extremity of the cold.

VI. The comparative march of the two glaciers bears a remarkable relation to their positions and form. In the Bossons we detect at once the sudden transitions and seemingly capricious changes of a torrent; in the Mer de Glace we have the stately and regulated flow of a river, in which the slighter variations are absorbed by the predominant inertia of a comparatively stable mass. Now the glacier of Bossons is, as every one who has seen it knows, a mere icy torrent, "a frozen cataract," which descends in a continuous mass from the level of the Grand Plateau of Mont Blanc to that of the Valley of Chamouni with very little impediment, with no confining bulwarks of rock, no contracting straits; and throughout this great vertical height of at least 9000 feet, the angle of descent is very steep indeed for so vast a mass. On the other hand, though the part of the Mer de Glace, called the Glacier des Bois under the Chapeau, is very steep, its "*régime*" is regulated by the supply derived from the reservoir glacier above, and, precisely as in rivers of great magnitude and length of course, and of moderate declivity, it yields sluggishly to impulsive or retarding forces which are checked and opposed by the multitude of sinuosities, the embaying of the ice in rock-bound expansions of the channel, the struggle of its passage through defiles and the enormous friction of its lower surface. Yet, lest we might attribute the irregularities of the torrential glacier to causes quite local and uncertain, we find them reflected more or less distinctly in the movements of the neighbouring one. Thus the anomalous retardation in the end of March and beginning of April appears in three stations out of four, as does that in the first half of June, showing clearly that it is not an error of observation. It appears that the thaw of the winter's snow during the month of May, saturating the pores of the glacier with water, produced (as we know that a thaw always does) a sudden and violent march, especially of the more susceptible or torrential glacier. So completely had this sudden move forced on the glacier of Bossons, encumbered by the spring avalanches and loaded with all the fragments and snow masses which had remained temporarily suspended during the winter months, that the lower part of the glacier (as we read in the memoranda to the register) advanced and widened greatly, to an extent which it had not done for many years past, and seemed to change its whole character; and in February a similar temporary increase of volume had taken place; "on ne s'y reconnait presque plus," writes Balmat; thus accounting for the particular accession of speed which appears in that month. In both cases, after the rapid march in February and in May, a reaction takes place; the material is deficient, the excessive pressure has been removed by the previous overflow, and a lull occurs in March and in June.

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* It will be seen from the temperature curves that the thermometer *fell* considerably in the latter part of June, both at Geneva and St. Bernard.

VII. These irregularities, such as they are, even should we fail in entirely explaining them, are at least not to be attributed entirely to errors of observation, since different observations (which it is to be recollected were sent to England in so rough a state that they required to be reduced and computed before the variations of velocity could be deduced from them) agree amongst one another, and agree with the phenomena casually noted in the Meteorological Register. They are very trifling in the movement of the Glacier des Bois, which presents a curve of remarkable regularity giving a minimum about the end of December, and a maximum in July. The coin cidence with the curve of temperature is greater throughout than we could have expected, considering the important difference of circumstances which occur in autumn and in spring when the thermometer stands nearly alike, the first chill of autumn depriving the glacier of its fluid pressure more effectually than the severer cold of winter which is tempered by its snowy covering, whilst in spring the first relaxation of the bands of frost saturates the icy mass with the impetuous streams of melted snow, as effectually as the intensest heat of summer. In fact, the velocity would probably be greatest in spring, were it not that then the ice has attained its greatest consolidation by the slow but continued effect of the winter's cold penetrating its upper layers, though after all probably to no very great depth. But this is undoubtedly the reason why the minimum and maximum approach so near to one another in point of time in the torrential glacier of Bossons, and it receives an important illustration from the independent fact of the observed condition of the source of the Arveiron, which (see the Meteorological Register), though very small in February, was still whitish and dirty before a change of weather, showing that the bands of frost were not so strong as to prevent a temporary relaxation of thaw throughout the mass of the glacier even in winter; and although the *mean* temperature of the air had been rising ever since the middle of January, and the greatest cold had occurred early in February, we find that at the end of March the source of the Arveiron was still as small as in February, and that owing to the coldness of the spring it had not even increased very much till the middle of April, when it almost suddenly resumed its summer volume. Now during all this time the velocities of the glaciers underwent but little change,—some oscillations backwards and forwards,—but took no real start until the frost had given way, and the tumultuous course of the Arveiron showed that its veins were again filled with the circulating medium to which the glacier, like the organic frame, owes its moving energy.

VIII. Being curious to see how far a relation might be established between the temperature of the air and the motion of the glacier independent of the irregularly acting causes above adverted to, I projected in Plate XI. fig. 2, the motions of the several points of the glaciers in terms of the temperature of the air for the periods already mentioned. It is to be recollected, however, that the observations of the thermometer were not made on the spot, and indeed it would have been difficult to have fixed upon a spot which should represent the mean circumstances of the whole glacier. Perhaps, therefore, the average of the observations at Geneva and St. Bernard (the mean of whose elevations is 4750 English feet above the sea, and therefore between that of Montanvert and Chamouni) may represent pretty fairly the climateric conditions of the inferior parts of the Glaciers des Bois and Bossons. Now, if we examine the curves of fig. 2, we are struck with *their almost perfect flatness until zero of the centigrade scale of temperature is reached*; but, the thawing point of ice past, the velocity manifestly goes on increasing with the temperature, in a ratio which would appear to be tolerably uniform if we neglect the irregular inflections of the curves.

IX. I am unwilling to multiply deductions which every intelligent reader will draw for himself; but one more I must add. It very clearly appears that the variaions of velocity due to season are greatest where the variations of temperature of the air are greatest, as in the lower valleys; but it also appears from Remark VIII., that variations of temperature below 0° centigrade, or 32° FAHRENHEIT, produce almost inappreciable changes in the rate of motion of the ice. Hence, from this circumstance alone, we should deduce that in the higher parts of the glacier (where, for example, it freezes almost every night in summer) the variations of velocity should be least, and indeed comparatively small at different seasons. This is well illustrated by comparing the summer motions of the stations D, A and C, mentioned in the first part of this section, with their annual motion, which exhibit a much slighter excess in favour of the summer period than in the lower stations which we are now discussing. The same thing was observed by M. AGASSIZ's surveyors on the glacier of the Aar, who at first saw, in this not very great inequality, an objection to my theory. On a more searching investigation, however, the objection disappears, as in their later writings they have acknowledged. Their position of observation far up on the glacier of the Aar, in a spot having a mean temperature near the freezing point if not lower, had a summer daily motion of 7·99 inches, and a mean daily motion during the whole year of 6·41 inches*. Now at station C, or the Pierre Platte, on the Mer de Glace, the mean motion for July 1842 was 10 inches, and for the whole year, 1842–43, it was 8·56 inches. It is quite evident that the motion of any point in the midst of a glacier is controlled by that of those which precede and follow it, and that it does not necessarily result, either that all must at once suffer a similar increase or diminution of speed, or that the times of maxima and minima, or even the general form of the annual curve, shall be the same. This leads to an important practical result which we shall follow out in the next section.

§ 8. *Summary of the Evidence adduced in favour of the Plastic or Viscous Theory of Glacier Motion.*

It is often difficult to obtain a calm and full hearing for any new theory or experimental investigation; not because there is any antipathy to novelty, or that experiment is undervalued, but simply because, in an age of bustle and struggle for pre-eminence, each man is so busy with his own reputation, or the means of increasing it, that he has no leisure to attend to the claims of others; to which may, perhaps, be added, that in the general diffusion of knowledge and acquirement, each reader, finding something in every course of experiment or reasoning which he knew, or thinks he knew before, is apt to run off with the chain of ideas which that one familiar link suggests, and losing patience to follow an argument of which he thinks he can, by his own penetration, anticipate the close. He sits in judgment on errors which are of his own invention, and confronts the author with arguments and opinions already thrice refuted and rejected by himself. In an age when all men would be teachers and all write for the press, the lot of an attentive reader falls to few.

I am far from saying that I have been more than usually unfortunate in this respect. But having, like others, seen my opinions disfigured for want of sufficient attention to apprehend them, or the arguments by which they are supported; ignorance of first principles hinted at, and even errors of observation imputed, where it was convenient that such ignorance and such errors should be presumed; I claim the privilege of stating afresh, though very briefly, the leading opinions which I do hold, and some arguments for them, which, if not altogether new, may be placed in a new light.

My chief analogies for the illustration of glacier motion have been drawn from the motion of a river, and by that comparison it in a great measure stands or falls. Slight and partial as is our knowledge of the mechanics of imperfect fluids, the explanation which I have given is founded upon that knowledge, and it appears to me to be sufficiently precise to warrant the inference of an identity of the mechanism in the two cases;—namely, that the movement is due to the internal pressures, arising from the weight of the mass, communicated partly or principally in the manner of hydrostatic pressure throughout a body whose parts are capable of moving or being shoved over one another (by that exertion of force which Dr. THOMAS YOUNG calls *Detrusive Force**, which overcomes what is commonly called the Friction of Fluids), so that the velocities vary from point to point of the moving body, being most rapid near the surface and centre, and least so near the banks and bottom.

So viscous fluids move, so bodies (even brittle solids, such as hard-boiled pitch) possessing the ordinary properties of solid bodies often do, if sufficient time and sufficient force be allowed†; the efficiency of time being chiefly this, that a pressure insufficient to produce instant detrusion, will, sooner or later, cause the particles to slide insensibly past one another, and to form *new attachments*, so that the change of figure may be produced without positive rupture, which would reduce the solid to a heap of fragments. This change may either take place without any loss of homogeneity, or by numerous partial and minute rents not everywhere communicating, and therefore not necessarily destructive of cohesion, which may be termed a bruise.

A glacier is not a mass of fragments.—As the analogy of the glacier to a river, in which the fluid principle is greatly in defect, and the cohering or viscous principle is greatly in excess, is the theory which I maintain, it is evident that the analogy of a stream of sand, or loose materials shot from a cart, or any other comparison with an aggregate of incoherent fragments or individual masses, must be wrong if mine be right. And I feel confident, not only that such an incoherent mass could not move after the manner of a glacier, but also that attentive inspection of a glacier at once contradicts such an idea.

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* Lectures, I., 135.

† See Professor GORDON's Experiment, Philosophical Magazine, March 1845.

On the *first* point, I maintain that a rugged channel, like that of a glacier, with a moderate slope, being *packed* with angular solid fragments, would speedily be choked, and that farther pressure from behind (for such a mass can only convey thrusts, not strains) would tend to wedge the fragments more tightly. Some grains of dry sand will slide easily down a plate of glass; but try to thrust it forcibly through a narrowing tube, or even a uniform one, the lower end of which rests on a surface over which the sand has poured, and your effort is vain, the tube will sooner burst; and even rocks may be blasted rather than the power of the wedge yield*. If the figure of the bed or channel be in any degree irregular, that is, have expansions and contractions, however smooth its surface, however small the sliding angle of ice upon that surface, the choking of a strait or contraction by the piling of the fragments will be as complete and effectual as if the lateral friction were excessive. Now in point of fact we have such cases as this;—a glacier 2000 yards wide (the Mer de Glace at the Tacul) issues by an orifice or strait 900 yards wide;—the glacier of Talefre, a nearly oval basin, pours out its annual overcharge by an orifice the breadth of which is but one-third of its lesser, one-sixth of its greater diameter†. On the supposition of jostling fragments, the facility of motion is increased, as the comminution is greater. The impossibility of the discharge of a fragmentary solid through a gorge by long stripes fractured parallel to its length, and constituting parallelopipedons of a certain breadth, is evident.

Crevasses.—In the *second* place, I maintain that actual inspection shows that a glacier is not the mass of fragments nor of parallelopipedons which some persons have, naturally enough at first sight, supposed it to be. In truth there is not an approach to such a condition in those glaciers which move over moderate slopes of considerable extent, which have very properly been assumed by all writers as the criterial examples of any theory; for it is not denied that portions of glaciers and glacier tributaries do sometimes fall piecemeal over precipices, each fragment descending by its separate and individual gravity, in the manner of an avalanche, although I am disposed to believe, indeed am sure, that the number of such instances is smaller than is usually imagined; and the angle requisite for such a tumultuous mode of descent is far greater than it has, perhaps, always hitherto been considered to be. To him who would form a just estimate of the mechanical constitution of a glacier—who would consider it as a whole—without *always* distracting his attention from the length and breadth of the problem by a minute attention to its lesser features,—I would earnestly recommend the frequent and attentive survey of a glacier or glaciers from a considerable elevation above their level and under varying effects of light. Had I confined myself to studying crevasses on the surface of the glacier, measuring their depths, injecting the ice with fluids and taking its temperature; useful and important as these inquiries are, (and I might almost include the fundamental and most important inquiry of all, that of ascertaining the velocity of its parts,) I should have been much longer in seizing the general truth of the individual character of a glacier, the importance of the fluid-like connection of its parts, the perfectly secondary importance or unimportance of the fissures by which it is often traversed. The traveller who winds his tortuous and sometimes perilous path amongst these crevasses, forgets, in the fatigue of his circumventions, in the wonder of his curiosity at their beauty and seemingly unfathomable depth, in the appalling steepness of their sides and the comparative insecurity of his own footing—he forgets, I say, in the midst of all these claims upon his attention, his curiosity, and his strength of mind, the comparatively large surfaces of unbroken ice over which he heedlessly walks, and the small, the very small depth at which most of the yawning crevasses which make such an impression on his imagination, dwindle into mere slits;—and when his walk is finished, he imagines that a glacier is a mere network of fissures interlacing in all directions. But let him gain a bold height above its surface, 800 to 1000 feet at least[*], so that the whole may be spread somewhat like a map before him, yet not too distant to prevent his seeing the number and forms of the crevasses, and estimating their area compared to that of the unbroken ice, his opinion is first shaken and then changed. He sees in the glacier a *whole*, which, regarded as such, is merely scarred, not dissected by these fissures;—he sees a mass as capable at least of conveying strains as thrusts; of which the cohesion is no more destroyed than (to use a comparison which I long ago employed) a parchment sieve is incapable of being stretched, because it is covered with fine slits.

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* See Huber-Burnand's conclusive experiments on this subject, Ann. de Chimie et de Physique, xli. 166, and Fechner's Repertorium, i. 65.

† See the Map of the Mer de Glace and its tributaries in my Travels in the Alps of Savoy.

I am confident that this will be plain to every unprejudiced person who will make the observation which I have recommended, and I have no hesitation in stating my belief that it will be found to be fully confirmed by M. Wild's map of the glacier of the Aar, should it ever be published; I say so without having any recollection how the matter stands, although I once had an opportunity of seeing that fine work for a few minutes; and the verification of this remark, by positive measurement, will, so far as I see, be the chief result likely to flow from the patient and disinterested labour of that competent surveyor.

But if this be true in a merely *superficial* plan, how much more true would it be if we could pare off the upper stratum of the glacier, and view a horizontal section of it at a depth of a hundred feet! The depth of the crevasses has, I am persuaded, been as much exaggerated as the thickness of the ice of the glacier has been underrated. In how few cases (where a glacier does not descend tumultuously) can we

[*] I may mention, as the very best stations which I am acquainted with, the summit or higher slopes of the hill of Charmoz above Montanvert, Station G*, above Trelaporte, and a point directly above the Couvercle at least 1200 feet higher than the Mer de Glace, which may easily be reached from the glacier of Talefre. Other glaciers offer of course similar points, but few so advantageous; the glacier of the Aar from the Schneebighorn, the lower glacier of Grindelwald from the slopes of the Mettenberg, the glacier of the Rhone from near the Mayenwand, and that of Zermatt from the Riffelberg, are examples.

let a plumb-line down even fifty feet without grazing the sides! and to what an insignificant fissure has the gaping crevasse dwindled even at that small fraction of the glacier's thickness! Supposing the crevasse to become uniformly narrower, how soon would it be extinct!

Again, the crevasses which traverse the surface of the glacier have almost always a determinate direction or directions, of which the simplest type seems to be that of perpendicularity to the veined structure*, which, generally speaking, occasions a convexity of the lines of fissure towards the origin of the glacier. Opposite Montanvert the crevasses form two systems inclined 65° to one another, but this appears to be a casual occurrence arising from a fresh strain being imposed on the ice owing to its rigidity when the direction of the bed or trough suddenly changes, and the two-fold systems probably coexist but for a short space, one tending to close whilst the other opens. Be this as it may, unless where a glacier is falling headlong in the manner of a cascade, the crevasses do not produce any actual dislocation of its mass into blocks or fragments, since the crevasses rarely intersect even where most numerous, but almost invariably *thin out* in the solid mass, whilst another crevasse takes its origin a little to one side or other, leaving a firm connection of ice between them; and the difficulty and danger of traversing a glacier where much crevassed, does not arise from the necessity of leaping from square to square of ice, but from having to traverse these bridges of icy communication, which even there link the glacier together, and which are almost always sharp on their upper edge when the season of the year is pretty far advanced, owing to the continual dripping.

The occurrence of crevasses which cut up a glacier into square or trapezoidal blocks, is sufficiently infrequent to deserve notice. Such occur when a glacier of the second order descends over a boss of granite, or a surface convex in all directions. We have then radiating crevasses combined with concentric ones, producing a tartan-like appearance. Such may be seen in a glacier of the second order on the south side of the Aiguilles of Charmoz and Grepon, above the Glacier du Géant; and it is a very convincing proof of the *essential tenacity* of a glacier, that, with a surface so scarred and intersected, the fragments do not fall away in avalanches. This only is to be explained by the consideration that, thin as are the glaciers of the second order, the apparent dislocation is only superficial.

Were the inequality of the central and lateral movement of the glacier mass to be attributed to longitudinal fissures or discontinuities, by means of which broad stripes of ice slide past each other, we should have to demonstrate the existence of such fissures, which could not be always close unless either (1) the surfaces were mathematically adapted to slide over one another, or (2) the ice possessed sufficient plasticity to mould the surfaces to one another's asperities, in which case the plasticity would alone be sufficient without the discontinuity to explain the motion of the ice. These longitudinal fissures, cutting the common transverse fissures perpendicularly,

Travels in the Alps, p. 171.

would divide the glacier even where most level into trapezia, and no transverse crevasse could be straight-edged but must be jagged like a saw, or cut *en échelon.* Such a phenomenon never occurs unless where a glacier is moving *torrentially*, or with great disturbance and down a steep. *There* such longitudinal fissures may occasionally be seen, but they form the exception and not the rule. It has been demonstrated by an elaborate proof in § 5, that the only trace of longitudinal discontinuity in the normal condition of the glacier is to be found in the veined structure, which, being caused by a partial discontinuity at a vast number of points, admits of an insensible deformation of the glacial mass without sudden or complete rents, or slips, or the formation of zigzag crevasses.

The existence of the great transverse crevasses, which, even in glaciers not moving torrentially, divide the surface of a glacier by rents perhaps 2000 feet long*, have been thought by some to be comparable to beams of an elastic material, supported at the two ends, and bending under their own weight forward, in the middle. Were this the case, it would scarcely modify the plastic theory as I have propounded it; because in order that such a bar of ice should conform to the known movements of the glacier, opposite the Montanvert for instance, the centre must continually gain upon the sides at the rate of 150 feet per annum at least, consequently the limit of cohesion of an elastic solid would soon be overpassed, and plasticity in the material sufficient to explain the whole motion would inevitably be admitted at last. Independently of this, it is evident, that were such a flexure essential to the motion, the lines of crevasses would be convex in the direction in which the glacier is moving instead of towards its origin.

Argument from the Equable Progression of Glaciers.—The equability of the motions of the various parts of a glacier, united as I have shown them to be by intricate relations†, must, I think, appear conclusive to every one capable of forming a just opinion on the subject, that the relative movements of the various parts of the glacier are due to the action of forces at small distances and to the antagonism of molecular cohesions and molecular strains, and not to the casual jumbling of a quantity of rude fragments. To myself, I confess that this now appears the strongest argument of all for considering the glacier as a united mass like a river, in which there is a nice equilibrium between the force of gravitation, acting by hydrostatic pressure, and the molecular resistances of the semi-solid; the degree of regularity of the law which connects the partial movements is wonderful, and I maintain that it is inexplicable except upon the viscous theory. Thus (1) the glacier moves continually, summer and winter, day and night, and never by fits or starts; for if it does—if gravitation overcomes mere friction, it occasions a shock or avalanche; (2) its mean annual motion is nearly alike from year to year; (3) the relative velocities of points widely distributed over the glacier (but exposed to similar influences of climate), change simultaneously in the same directions, often in the same proportions; thus "the variation of velocity the breadth of a glacier is proportional to the absolute velocity at the time of the e under experiment[*]." (4) The progression of velocity from the side to the centre marked by insensible gradations[†]. (5) When we compare the motion of a given oint of a glacier any day of one year and the same day of another, the probability s that the velocity will be exactly the same, if the season be equally hot or cold; ence, surely, a most unexpected result, which I first announced in 1842, that *a few lays' observation of a glacier will enable any one to compare its mean rate of motion ver its various parts and with different glaciers.* Thus, the motion of a point marked D 2 on the Mer de Glace, was in 1842, from August 1 to August 9, 16½ inches daily; from August 9 to September 16, 18 inches; now next year, 1843, *one* observation at the same point in August gave 16 inches; and in 1844, *one* observation in September gave 17½ inches. But still further, (6) the very law of flexure of the ice is the same from year to year: a series of stations across the ice at the Montanvert gave, in 1842, the following (simultaneous) relative velocities[‡]:—

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* Travels, p. 171, 2nd ed.

† See § 5 of this paper, pages 167 and 168.

1·000   1·332   1·356   1·367.

The same points being recovered in 1844, the relative motions were (by a single observation of the space moved over in five days)—

1·000   1·339   1·362   1·374,

ratios almost the same but slightly increasing, which corresponds with the fact mentioned above (3), that when the absolute velocities are greater, the relative velocities are so too, which was here the case, for the velocity denoted by 1·000 was a little greater in the second case than in the first.

Tensions and Thrusts.—The occurrence of open crevasses plainly indicates the existence of strains in the ice of glaciers producing disruption, at least partially. Hence some writers have precipitately inferred that the whole glacier must be in a state of tension; an uncertain inference surely in a problem of singular complexity, and one which is not warranted by a more accurate analysis. Yet for a time rival theories seemed poised on the inappropriate question, "Are glaciers in a state of internal tension or compression?" Even if the glacier moved as a mass of fragments, therefore without tension, the cohesion must first have been broken before it could be reduced into fragments. I have been inconsiderately censured for quoting, with approbation[§], the observation of M. Elie de Beaumont, that a glacier appears to be rather in a state of distension than compression, whilst I adopted a hydrostatic pressure, acting from the origin as the source of motion. A careful examination of the passages in question will show that my assent to the view of M. Elie de Beaumont was limited to *portions* of the glacier, and especially to those portions most crevassed, the parts, namely, which connect the sides and centre, and which serve to drag the more sluggish, because retarded, lateral portions after the freer central part on which the *vis a tergo* acts with most advantage; and in a direction generally parallel to the blue bands, so far as they are due to inequalities of motion in the horizontal plane*. My earliest attempts to obtain clear views of the internal forces acting on a semi-rigid body, impelled by self-contained hydrostatic forces, convinced me how little could be founded on the completeness of any mathematical investigation of them, which in our present state of knowledge may well be considered as hopeless; and reserving to myself the not so difficult task of extricating at a future time the more important practical laws of these strains and thrusts, I very carefully avoided, in my first publication, any allusion to what might be considered as their actual distribution; a distribution varying not only from point to point of the glacier surface, but throughout its thickness, and most undoubtedly varying also for the same point at different seasons of the year, or even changing its sign, so that a tension at one season may become a thrust at another.

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[*] Travels, p. 148.

[†] See § 5 of this paper.

[‡] Travels, 1st edit., p. 146.

[§] Travels, 1st edit., pp. 178, 370; 2nd edit., p. 370 and *note*.

I had no reason to repent of this caution, from which I only departed so far in my Seventh Letter on Glaciers, published subsequently, as to deduce in an approximate manner, from elementary mechanical laws, the directions of the *surfaces of tearing* within such a mass as I had described, upon the simple supposition that the hydrostatic pressure acting uniformly, the tendency of motion of any particle will be in the direction of least resistance when all the resistances are taken into account, and that the surfaces of rupture will divide particles whose motions are dissimilar, but will not divide particles whose motions are alike. I repeat that I had no reason to repent of my abstinence from theorizing, when I found that a far better mathematician than myself, taking up the inquiry where I had left it, and after applying himself for a long time to the exclusive mechanical considerations which the viscous theory had suggested, left the subject, as I conceive, little more advanced than he had found it, and fell into some mistakes and inconsistencies, almost inseparable from this way of treating a problem which extensive observation and patient thought can alone disentangle.

Formation of Crevasses.—It has been seen in the third section of this paper, that De Saussure, and almost all his successors, have regarded the crevasses as *accidents* of glacier motion, and not essential to it; and in this view I of course concur. Nevertheless, the study of crevasses is one of considerable, though secondary interest, and is very far indeed from being completed. It requires, among other things, a very sedulous attention to the state of the glacier at various seasons, and even whilst covered with snow; and it requires further a two-fold classification of crevasses, into those which may be considered as proper to the mass of the glacier, and those which merely seam its surface.

I will first speak of the last point.

Though the formation of a crevasse betokens a local distending force, such a force cannot with any certainty be referred to the whole depth of the glacier below the point where the chasm opens. On the contrary, there is a fully greater probability that under that very spot the ice is compressed. If one cause of a crevasse be, as is universally acknowledged, a protuberance or inequality in the bed over which the ice is impelled, for the same reason that a beam, broken by means of weights, is in a state of longitudinal compression below, where its surface is concave, and of distension above, where its surface is convex, the cracks in the glacier may be due solely to this last and partial cause. Superficial crevasses may consequently be occasioned where there is no *general* distension of the mass, either (1) by the shoving of the semi-rigid glacier as a whole, over a convex declivity, or (2) from an internal turgescence arising from hydrostatic pressure, resisted by the intense friction of the anterior or more advanced parts of the glacier, which, causing the line of least resistance to be upwards and forwards, forces the pasty mass to tumefy or increase in thickness, exactly as it has been seen in § 2, p. 153, that sluggish lava streams do in a similar case. But if the tumefaction be pushed beyond the limits of plasticity of the superior and more distended portions, they must burst and assume the crevassed forms actually observed in the plastic models described in p. 144. Hence the existence of crevasses not only does not always result from a state of *general* distension in the glacier, but may arise from the precisely contrary condition of great internal compression. This argument is well illustrated by the recent observations of M. AGASSIZ's co-operators on the glacier of the Aar, whose observations I have elsewhere shown[*] to be incompatible with any other view than that of intense longitudinal compression in the mass generally, and yet the surface abounds in crevasses of the usual form and dimensions.

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* See Philosophical Magazine, May 1845, p. 408.

The manner of formation of crevasses generally, including such as may betoken a real distending force acting on any part of a glacier throughout its thickness, is not only a most curious question in itself, but suggests others which a correct theory of glacier motion can alone answer. If a crevasse once formed remain a fissure in the ice for ever after, why is the horizontal projection or ground plan of the crevasses of a canal-shaped glacier convex towards the origin of the glacier, and not protuberant in the direction of its motion, as the ascertained greater velocity of the centre would assign? Why are the crevasses for the most part vertical and not inclined forwards, or at least not notably so, on the same account? Why, if the glacier be urged downwards by a longitudinal force distending it, do not the crevasses continually widen in proportion as they are further from the origin? These questions seem incapable of a sound answer except by supposing that the crevasses are, at least in a great degree, the fresh production of every spring, and arise from the sudden start which the glacier makes when that extremity which descends into the valley begins to experience the thawing effects of returning summer. I should not wish to speak positively upon what involves a difficult if not impossible observation,—the state of the glacier with respect to crevasses whilst still under the winter's covering of snow. But the fact of the transverse direction of the crevasses, or even their convexity towards the origin, from year to year, seems to admit of no other explanation. But besides this, I can affirm, from a careful observation of the crevasses of the Mer de Glace from June to September in one year, that the changes which they underwent were such as preclude the possibility of a crevasse of autumn being merely preserved by the snow of winter, and re-appearing afresh in spring as it had done the previous one. The thing is impossible, because the character of the crevasse is essentially altered. In order that an autumnal crevasse may become a spring crevasse it must be sealed up, annihilated, and opened again. A glance at the three sections in Plate X. fig. 3, will illustrate this. No. 1 shows crevasses freshly opened soon after the snow has quitted the surface of the ice—the edges are sharp, the sides vertical, the openings so small that they may be easily stepped across, and in other instances they are not wider than may admit the blade of a knife. No. 2 shows the crevasse opened to its widest extent by the acceleration of the motion, by the force of the sun which has altogether wasted away the side with the southern exposure, and by the copious drippings of the melting ice and mild rain. No. 3 (which as well as No. 2 is taken from a sketch on the spot, No. 1 being done from recollection) shows what I have elsewhere called the state of collapse of the glacier, which affords the most direct possible evidence of its plastic condition; for we there see, not merely the prominences worn away and blunted by the heat of summer, but subsiding into the hollows, the crevasses being choked by the yielding of their sides, and the glacier again resumes a traversable character, only that the plane surface of spring is changed into irregular undulations preparatory to a complete amalgamation of the whole glacier into one mass*.

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[*] Ninth Letter on Glaciers. Appendix to Travels, 2nd edit., p. 443

The collapse is thus described in my Journal of 1842, written at the time, and therefore more emphatic and unbiassed than after my theoretical views had been matured and published. "1842, Sept. 16, Friday. The level [of the Mer de Glace at the 'angle'] has sunk since the 9th of August, nine feet $8\frac{1}{2}$ inches. The effect of this immense fall is abundantly evident in this part of the glacier. On my first visit this time [*i. e.* after an absence of a month], on the 10th, I was quite struck with its shrunk appearance, as I was today with the collapsed state of the crevasses. There cannot be a question but that the glacier has subsided bodily into its bed, and that the semifused pliancy of its materials causes them to recover a uniform and lower level. The crevasses are much less deep than in July and August, as at that time they were larger and more numerous than in June. They are collapsed and (opposite Trelaporte) almost soldered up; the edges all rounded and melted by the sun's heat." The phenomena here described, "the shrunk appearance," "the *semifused pliancy*," "the soldered crevasses," "the rounded edges," convey to the attentive spectator an intuitive conviction of the plasticity of ice at the thawing season, which no words can express, no mathematical symbols weave into a demonstration. I can only say that it is easier to believe than to disbelieve; and that sooner or later, it will, I doubt not, be generally admitted.

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* See Travels, p. 174; and Fourth Letter on Glaciers.

Considering the crevasses as chiefly superficial in the normal glacier (I mean that of which the inclination is not excessive), it is evident that the formation of the crevasses must depend mainly upon the configuration of the bed. Where the section of the bed parallel to the length of the glacier is convex upwards, there the tension at the surface will cause the crevasses to expand; when the bed is concave and the surface is being compressed, the crevasses tend to close. Hence the surface of the glacier descending an irregular bed may be alternately in a state of distension and compression, and the crevasses do not tend to widen indefinitely, which would be the case if the whole glacier were distended. This tendency in the crevasses to expand and contract in accordance with their position is beautifully seen in viewing the Mer de Glace from a height, as we have recommended. The steep fall opposite Trelaporte shows the expansion of the crevasses, but the comparative level opposite the little glacier of Charmoz gives it time to recover its solidity by the general closing of the crevasses under compression. The careful study of such a scene as this gives a more clear insight into the glacier phenomena than any other part of the inquiry, excepting only the measurement of velocities.

Law of Velocities.—To these velocities we now return. The varying velocities in different glaciers, at different seasons and in different parts of the same season, are all in accordance with the motions of a viscous or plastic body. They depend upon the slope, being greatest, *ceteris paribus*, when the slope is greatest; and upon the climate to which the glacier is exposed, being greatest in glaciers which descend into deep valleys, and least in those which, though very steep (such as that of the Schönhorn described in § 6), are placed in so elevated and therefore dry and cold an atmosphere as to afford in sufficient water to moisten the snowy mass or *névé*, and which are therefore endowed with very feebly hydrostatic qualities. This is demonstrated on the one hand by the extreme smallness of their motions, and on the other by the insignificant streams of water to which they give birth even in the height of summer. In any individual glacier the velocity of the parts must (on any theory) vary with the area of section through which the ice stream has to pass; but yet it may happen that the contraction of a valley, if not accompanied (as is often the case) with an increased slope, will oppose so great a resistance to the efflux of the mass, that under intense longitudinal compression its forward motion is retarded, and the condition of uniform discharge is satisfied by the accumulation of the ice in a vertical direction, the rise of the surface being necessarily accompanied with a thrust from below upwards, and a sliding of the particles over one another in that direction. This appears conclusively to be the case for a great extent of the lower part of the glacier of the Aar, as already mentioned, and affords the most direct evidence which could be desired, that the kind of internal motion necessary for producing the *frontal dip* in the veined structure (which arises from tearing or crushing in sliding in the vertical plane*) was correctly foreseen.

The law of velocities at different points of the axis of a glacier from its origin towards its termination, must evidently depend upon the configuration of each particular glacier. It may be constantly increasing from the origin to the extremity, it may be diminishing, or it may have alternations of increase and diminution; and upon this circumstance the frequency and magnitude of the crevasses will mainly depend. But the *régime* of the glacier, by which we mean to express the combination of circumstances determining its motion, varies from one season of the year to another, owing not only to the general influence of heat and cold, but also to the progressive communication of that influence to portions of the glacier in successive stages of elevation. Evidently the extremity nearest to the valley will receive the earliest and most violent impression of solar heat, whilst the middle and upper regions are involved in complete winter. Partial dilatations must take place in spring, partial condensations in the decline of the year; as is evident from the consideration that temperatures inferior to freezing do not sensibly affect the motion of the ice (see above, p. 192) which higher temperatures do, consequently the influence of season will be chiefly felt in those parts of the glacier where the temperature of the air seldom falls in summer to 32°, whilst the more stable motion of the higher part acts as a drag or equalizer upon the whole system. The condition of violent distension produces crevasses, that of violent compression produces the frontal dip of the veined structure, or that share of it which is due to the relative motions in a vertical plane. The longitudinal veins will result whether the axis of the glacier be distended or compressed. Hence the reason why the frontal dip is difficultly seen in all the middle region of a glacier, which like the Mer de Glace, is subject to much extension due to great and increasing declivity, and to be well seen must be sought for in the higher parts of the glacier, as above Trelaporte, at the foot of the Couvercle†, and in glaciers subject to great compression, as that of La Brenva, the glacier of the Rhone, the Aar, &c.

Ablation of the Surface.—One phenomenon is most satisfactorily explained by the variations of velocity established and illustrated in this paper. The collapsed state of the glacier after the hot summer of 1842, and the absolute lowering of its surface level by thirty feet in the space of a few months, had struck me as requiring an energy altogether extraordinary in kind and degree to restore next spring the level which had been lost, in order to allow for an equal ablation the succeeding summer; and at first I was disposed to admit so much of the dilatation theory to be true as would account for the swelling of the surface in a vertical direction by the freezing during winter of the infiltrated water‡. Further reflection convinced me however that this explanation was insufficient and also not required, and I accordingly concluded

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* Seventh Letter on Glaciers. Appendix to Travels, p. 435.

† Travels, 2nd edit., p. 167.

‡ Fourth Letter. Travels, App., p. 415.

"that the main cause of the restoration of the surface is the diminished fluidity of the glacier in cold weather, which retards (as we know) the motion of all its parts, but especially of those parts which move most rapidly in summer. The disproportion of velocity throughout the length and breadth of the glacier is therefore less; the ice more pressed together and less drawn asunder; the crevasses are consolidated, while the increased friction and viscosity causes the whole to swell, and especially the inferior parts, which are most wasted*." I have nothing to add to this explanation, except that the observation of the motion throughout the whole year confirms it in every particular. The more elevated portions of the glacier, which during a large portion of the year are exposed to a mean temperature under 32°, move in a manner comparatively uniform, the lower extremities undergo great oscillations in their speed (in the ratio of four or five to one; see page 185); hence the attenuation during the summer *régime* which is owing to the drag taking place downwards in an excessive degree; but the winter's cold, equalizing in some measure the velocity everywhere, brings the plasticity into full action, fills the crevasses and swells the surface to its old level.

As it is universally admitted that the glacier proper does not grow in thickness by snowy accumulations, the important variations in its level in different years† cannot be ascribed to the severity of certain seasons increasing the mass of snow falling upon it, but rather to the prolongation of the winter cold into spring and summer, which causes the condensing or accumulating process to be in excess, and therefore the thickness of the plastic mass to accumulate beyond its due amount.

Thus we have the following phenomena, all independently observed, reconciled and explained by one hypothesis; the general convexity of the crevasses upwards, notwithstanding the excess of motion in the centre; the general verticality of the crevasses, notwithstanding the retardation of the bottom; the perfect state of the crevasses every spring succeeding their visible collapse in autumn; the ascertained velocity of different parts of the glacier, and the diversity of the annual changes which these velocities present; the seemingly opposed facts showing the glacier to be subjected to powerful tension, producing crevasses, and yet to be under a compression which produces in some places the *frontal dip*; and finally, the renewal of the level of the ice during winter, which has been lost partly by superficial melting, but as much or more so by the attenuation and collapse of the glacier during summer. These various effects of one cause, though they do not embrace all the phenomena of glaciers, certainly include a very remarkable and complicated group of facts.

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* Travels, p. 386, 2nd edit.

† For instance, it has been seen from Balmat's narrative (p. 189 above), that in 1845 the glacier attained a much higher level at the *Angle* than it had done for three previous years at least, since all the marks of measurements which were cut on the rock in 1842 were concealed; and he attributes this, apparently with reason, to the extreme lateness and coldness of the spring.

Plasticity—Veined Structure.—I certainly never expected, when promulgating the viscous theory, that it would have met with so much opposition on the ground that the more familiar properties of ice are opposed to the admission of its plasticity; and that the fragility of hand specimens should be considered as conclusive against the plastic effect of most intense forces acting on the most stupendous scale upon a body placed in circumstances which subject it to a trial, beneath which the most massive constructions of the pyramid-building ages would sway, totter, and crumble. In an age when generalizations of the more obvious kinds are no longer proofs of genius and perspicacity, and when popular writers on science delight to startle their readers by showing how bodies the most dissimilar possess properties in common; in an age in which *gradations* of properties and organs have been studied with such persevering sagacity, and in which so many unexpected qualities have been discovered;—when iron is classed as a combustible, when metals are found which float on water and which catch fire on touching ice, when a pneumatic vacuum is formed and maintained in vessels five miles long, and whose sides are ripped open twenty times a day;—when, moreover, the simpler abstractions of former times are being daily overset, when no body seems to possess any one property in perfection, and all seem to possess imperfectly every quality admitting of degree; when adamant is rejected from our vocabulary, and softness means only less hardness, and the definition of a perfect fluid is as imaginary as that of a solid without weight;—when a vacuum and a plenum are alike scoffed at, and even the heavenly bodies toil through media more or less resisting; when no substance is admitted to expand uniformly by heat, when glass may be considered a conductor of electricity, and metals as imperfect insulators;—in these days, when the barriers of the categories are so completely beaten down, I had not expected to meet with so determined an opposition to the proposition that the stupendous aggregation of freezing water and thawing ice, called a glacier, subjected to the pressure of thousands of vertical feet of its own substance, might not under these circumstances possess a degree of yielding, moulding, self-adapting power, sufficient to admit of slight changes of figure in long periods of time. Still less could I have anticipated that when the plastic changes of form had been measured and compared, and calculated and mapped, and confirmed by independent observers, that we should still have had men of science appealing to the fragility of an icicle as an unanswerable argument! More philosophical surely was the appeal of the Bishop of Annecy from what we already know to what we may one day learn if willing to be taught: "Quand on agit sur un morceau de glace, qu'on le frappe, on lui trouve une rigidité qui est en opposition directe avec les apparences dont nous venons de parler. *Peut-être que les expériences faites sur de plus grandes masses donneraient d'autres résultats*[*]."

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[*] Théorie des Glaciers de la Savoie, p. 84. Quoted in my Travels, p. 367, 2nd edit. Since this paper was read, Mr. CHRISTIE, Secretary of the Royal Society, has kindly communicated to me a very striking remark upon a well-known and easily-repeated experiment. The experiment is this. If, in the course of a severe

The "ductility" is indeed not great; the compact ice even of the slowest moving glaciers bears evidence, in the veined structure, or "blue bands," to the bruise which it has received from the all-powerful strain which has acted on it. When the difference of motions is excessive, or the slope occasions the speed to be greater than permits the gradual molecular adaptation of the semi-rigid parts to one another, the masses are broken up and fall more or less tumultuously; *the strain being then removed by the dislocation, the veined or bruised structure is invariably extinguished at last.* I shall quote a series of examples of the gradation of phenomena, which I conceive to be plainly connected by a common cause.

1. In any torrential glacier, such as the Glacier des Bossons, the upper part of the glaciers of La Brenva, Allalein, or the Rhone, and many others, the fractures are so numerous that the ice descends in blocks, almost as water in a cascade often does in spray, and hence the internal strains being destroyed, no structure is developed, or if previously developed, tends to wear out*.

2. In a glacier moving torrentially, that is with frequent and considerable changes of velocity, but without being divided into blocks by intersecting crevasses, we find real internal cracks in the ice, some feet in length, and an inch or more in thickness, marked by the pure frozen water which fills these spaces in the comparatively opake whitish ice of which glaciers descending rapidly from the region of the *névé* are composed. Such are peculiarly visible in the lower and more accessible region of the glacier of Bossons†; perhaps the most instructive which can be named as showing these infiltrated cracks, which by their dimensions, direction, and in every other particular, form a true link between the longitudinal dislocations of a torrential glacier, and the perfect veined structure or bruise into which it passes by imperceptible gradations, including a perfectly regular development of the frontal dip, where we might expect it to be well shown, for the observations of page 184 show that the lowest portion of

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winter, a hollow iron shell be filled with water and exposed to the frost with the fuze-hole uppermost, a portion of the water expands in freezing, so as to protrude a cylinder of ice from the fuze-hole; but if the experiment be continued, the cylinder continues to grow, inch by inch, in proportion as the central nucleus of water freezes. "In the first instance," says Mr. CHRISTIE, "a shell of ice containing water was formed, no doubt, within the iron shell, and the fuze-hole might be filled by the expansion of the water in the act of freezing; so that there may be no reason for attributing plasticity to the ice as far as this goes; but the shell of ice once formed, and the fuze-hole filled with ice, the subsequent rise of the ice must have proceeded from the ice of the interior shell being squeezed through the narrow orifice. No thawing took place during the process. Does not this show plasticity even in very small masses of ice?" I have also been lately informed, on excellent authority, that in a new work by a most eminent German mineralogist, the plastic character of ice in masses is assumed as an admitted fact. In corroboration of what has been said in the text, I may farther add, that whilst these sheets are passing through the press, I observe in the Athenæum (June 20, 1846), an account of a patent process for moulding solid tin into tubes and other utensils, in the course of which it is stated that "tin under a pressure of about twenty tons to a circular inch, will *run* according to the law of fluids."

[*] See Third Letter on Glaciers. Travels, Appendix, p. 407.

the glacier of Bossons moves slower than its middle portion; there is therefore a manifest longitudinal compression arising from the friction of the bed*.

3. The next stage is that of the perfect bruise or veined structure, best seen in the most united and least fissured parts of glaciers with rocky sides and moving over a moderate slope. Whatever increases lateral compression (without however necessitating dislocation), such as the union of two or more glaciers in one, tends to develope the structure more perfectly†. Such cases are well seen on several parts of the Mer de Glace, and of the glacier of Miage‡.

4. In very wide glaciers, moving with feeble velocities, the veined structure is slightly developed, except near the sides, simply because the *twist* being small the ice is hardly bruised. Nor can we wonder to find the structure at the distance of many hundred yards from the sides of a vast slow-moving glacier of this description, if developed at all, to be complex and irregular, exhibiting twists such as I have figured in my Travels, p. 164, and which are peculiarly conspicuous in the magnificent glacier of Aletsch. This circumstance finds a precise analogue in the case of a great river, such as the Rhine, or indeed in any river moving with a very slight inclination; the excess of velocity of the central above the lateral parts, not very great at any rate, is distributed over such a space that the slightest casual disturbance of the current, from an irregularity in the bottom or sinuosities of the course, produces local differences of velocity, occasioning ripples and eddies in various parts of the breadth. If these ripples and eddies, in other words, differential motions of adjacent particles, could be visibly represented by using differently coloured fluids, they would undoubtedly afford sections exhibiting undulations and contortions exactly like those which the ice presents in the cases mentioned above. We claim therefore the apparent exception as a real proof of our general rule.

5. In the *névé* proper, no true veined structure is developed; *first*, because, whilst the mass is snowy, its powdery nature yields without admitting of a fracture or bruise; *secondly*, because the true *névé* has rarely any lateral compression worth mentioning, being widely spread and not contained between steep barriers; *thirdly*, because its motion is altogether very small; *lastly*, because its extreme dryness does not afford water enough to percolate its substance and there to be frozen; when it does so, it ceases to be *névé*.

On these grounds I hope that the theory of the veined structure, so important to that of glaciers, may be considered as explaining a number of intimately connected phenomena.

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* The internal rents in the lava of Zafarana referred to in § 2 of this paper, and figured in Plate IV. fig. 8, present a perfect analogy with those of the glacier of Bossons, and appear to be due to the same cause.

† Third Letter. Travels, Appendix, p. 407.

‡ See the figures of the structure of the glacier of Miage. Travels, p. 197.

"The glacier struggles between a condition of fluidity and rigidity*." "A glacier is not a mass of solid ice, but a compound of ice and water more or less yielding, according to its state of wetness or infiltration†." "The pressure communicated from one portion to the other, will not be the whole pressure of a vertical column of the material equal in height to the difference of level of the parts of the fluid considered; the consistency or mutual support of the parts opposes a certain resistance to the pressure, and prevents its indefinite transmission. * * A glacier is not coherent ice, but a granular compound of ice and water‡." "When the semifluid ice inclines to solidity during a frost, the motion is checked; if its fluidity is increased by a thaw, the motion is instantly accelerated. * * It is greater in hot weather than in cold, because the sun's heat affords water to saturate the crevasses§." Such were the terms in which within a few months after suggesting the viscous theory I expressed my opinion of the influence of the compound structure of the glacier, a mass composed, not of ice alone, but of ice including water in its countless capillaries never frozen‖ even in winter. The quality of plasticity or viscosity resulting from the union of a nearly perfect fluid with an imperfect solid is seen in very numerous and familiar instances, as for instance in sand, which is itself devoid of any tenacity until its interstices have been saturated with just so much water as to cause it to flow; or in the still more familiar instance of water-ice prepared for the table, in which the varying proportion of the solid and fluid ingredient gives to it every shade of consistency, from a brittle solid to a liquor including suspended solid grains. The prodigious effect of capillary infiltration in determining the motion of even the most solid and ponderous bodies, breaking up their parts, and giving to the motion of the whole a more or less river-like character, is seen in the frequent case of land-slips, as for instance that of Goldau. And scarcely less instructive are the numerous examples, cited in the first section of this paper, of huge masses of almost cold and brittle lavas being pressed on with a uniform and graduated motion, by the almost unimpeded hydrostatical communication of pressure from the yet active fluid which circulates unseen in their pores. With this analogy before me, I replied in 1844 in the following terms to the question, "How far a glacier is to be regarded as a plastic mass?" "Were a glacier composed of a solid crystalline cake of ice, fitted or moulded to the mountain bed which it occupies like a lake tranquilly frozen, it would seem impossible to admit such a flexibility or yielding of parts as should permit any comparison to a fluid or semifluid body transmitting pressure horizontally, and whose parts might change their mutual position so that one part should be pushed out whilst another remained behind. But we know in point of fact, that a glacier is a body very differently constituted. It is clearly proved by the experiments of AGASSIZ and others, that the glacier is not a mass of ice, but of ice and water; the latter percolating freely through the crevices of the former to all depths of the glacier; and as it is matter of ocular demonstration, that these crevices, though very minute, communicate freely with one another to great distances, the water with which they are filled communicates force also to great distances, and exercises a tremendous hydrostatic pressure to move onwards in the direction in which gravity urges it, the vast porous crackling mass of seemingly rigid ice in which it is, as it were, bound up*."

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* Third Letter on Glaciers, August 1842. Appendix to Travels, p. 407.

† Travels, 1st edit., 1843, p. 175.

‡ Travels, p. 367., edit. 1843.

§ Ibid. p. 372.

‖ Ibid. p. 361, 372.

Now the water in the crevices does not constitute the glacier, but only the principal vehicle of the force which acts on it, and the slow irresistible energy with which the icy mass moves onwards from hour to hour with a continuous march, bespeaks of itself the presence of a fluid pressure. But if the ice were not in some degree ductile or plastic, this pressure could never produce any, the least, forward motion of the mass. The pressure in the capillaries of the glacier can only tend to separate one particle from another, and thus produce tensions and compressions, *within the body of the glacier itself*, which yields, owing to its slightly ductile nature, in the direction of least resistance, retaining its continuity, or recovering it by re-attachment after its parts have suffered a bruise, according to the violence of the action to which it has been exposed.

The action of warm weather in accelerating the movement of the glacier is plainly due to the abundance of the water saturating its pores; but this may act in two ways; first, by rendering the frame-work of ice less brittle when it is in the very act of dissolving by the circulation of water in a perfectly fluid state through its pores†, and secondly, and more particularly, from the hydrostatic effect of *gorging* a porous mass with fluid. When an incipient frost dries even momentarily the surface of the glacier, the vast porous mass begins to *drain*. This is a very slow process, owing to the resistance to the passage of a fluid through very long and complicated canals. Were it not so, glaciers would be entirely dry after sunset and in winter, which is not the case. The hydrostatic pressure within the whole glacier is however sensibly diminished by the process of drainage; this is evident from watching the level of water in a vertical hole of any depth made within the solid ice of the glacier. After much rain or heat this level is always higher than after dry cold. In the former case the glacier may be said to be gorged, the supply of water from the surface exceeding the power of the drainage to carry it off. The circulating vessels are therefore overcharged. In the latter case the superficial supply is stopped, the drainage goes on slowly though uninterruptedly, and the level of the water in the vertical shaft slowly descends, indicating the diminution of internal pressure. If it were not for the capillarity of the ducts, it is plain that no effective hydrostatic pressure would be developed at all; the flow being equal to the supply, no part of the *vis viva* would be expended in producing internal pressures. With this concluding observation I commit the Plastic or Viscous Theory of Glaciers to the impartial judgment of those qualified to decide on its merits in explaining facts, and on the variety of difficult and complicated considerations which opposed and still oppose themselves to a complete development of it.

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* Sixth Letter. Appendix to Travels, 2nd edit., p. 428.

† This I think is undeniable, from the appearance of the collapsed crevasses above referred to, notwithstanding the difficulty of imagining any variation in the sensible heat of water circulating in ice. It is not the only fact in the glacier theory which seems to require some modification of the commonly received laws of latent heat at the very limit of congelation and liquefaction.

Edinburgh, Jan. 10, 1845.

XV. *Supplement to a Paper "On the Nervous Ganglia of the Uterus."*

By Robert Lee, *M.D., F.R.S., Fellow of the Royal College of Physicians, London.*

Received June 14,—Read June 19, 1845.

In the First Part of the Philosophical Transactions for 1841, I have described and represented in two engravings the nervous ganglia, situated on the sides of the neck of the uterus, in which the great sympathetic and third sacral nerves unite, and from which branches proceed to the vagina, bladder, rectum, and the whole of the lower part of the uterus. In an Appendix to that paper, published in the Second Part of the Philosophical Transactions for 1842, there is contained a further account of the nervous structures situated on the fundus and body of the uterus, and an engraving in which the appearances they present at the full period of gestation have been accurately delineated. From the form, colour, vascularity, and general distribution of these structures, and from their branches actually coalescing, and being continuous with those of the great sympathetic and spinal nerves, I inferred that they were true nervous ganglionic plexuses, and formed the nervous system of the uterus enlarged during pregnancy.

In a gravid uterus at the full period I have recently, and with still more care, traced the great sympathetic and spinal nerves into the two hypogastric ganglia, and from thence over both sides of the uterus to the fundus. A lens which magnified six diameters was employed in this dissection, which enabled me with unerring certainty to distinguish and to separate the nervous filaments from the fine cellular membrane by which they are so closely surrounded, and from all the other contiguous structures. In this minute dissection, many of the details of the nervous system of the uterus are more perfectly shown than in any previous dissection made by me, and they confirm, in the most complete manner, the accuracy of all that is contained in my previous communications on this subject to the Royal Society. To this preparation I can now appeal, as affording a perfect demonstration of the truth of all my statements respecting the ganglia and other nervous structures of the uterus.

XVI. *On the Nerves of the Uterus.* *By* THOMAS SNOW BECK, *Esq., Surgeon.* *Communicated by Sir* BENJAMIN C. BRODIE, *Bart., F.R.S.*

Received May 29,—Read June 19, 1845.

IN February 1843, during the examination of the body of a woman who died from uterine hæmorrhage immediately after delivery, it occurred to me that the uterus afforded a good opportunity for examining the condition of the nerves in the impregnated state, to which attention had been directed by Dr. ROBERT LEE in communications to this Society in the years 1841 and 1842. With the view of confirming the researches of Dr. LEE, I commenced the dissection of the nerves of the gravid uterus, but found so many points at variance with his published statements[*], and the nerves so small, considering the size of the organ, that it appeared very doubtful whether or not they had increased in size during pregnancy; but in order to arrive at a correct conclusion on this point, a comparison of the nerves of the unimpregnated with those of the gravid uterus was indispensable; and in the following year I commenced a dissection of the nerves of the unimpregnated uterus and of the neighbouring organs.

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[*] To the structures described as nervous ganglia and plexuses, Dr. LEE gave the following names: "The posterior subperitoneal ganglion and plexuses," "a great nervous web under the peritoneum," to which "it adheres firmly," and which covers the posterior surface of the uterus "as high as the fundus." "It represents the appearance of a layer of dense structure composed of fibres strongly interlaced together, having a yellowish-brown colour." "The anterior subperitoneal ganglia and plexuses," "a nervous and vascular mass of great extent, and similar in structure to the subperitoneal ganglia on the posterior surface." It "adheres to the peritoneum firmly," and covers "the whole anterior surface of the uterus." "The left subperitoneal plexuses." "Another ganglion of considerable size," "near the edge of the uterus." "The great transverse plexuses," "which proceed across the uterus," and "present the appearance of a white, pearly fuciculated membrane about a quarter of an inch in breadth." "The left spermatic ganglion," "a dense reddish-brown coloured mass consisting of fibres firmly interlaced together." "The hypogastric or utero-cervical ganglion," which "exceeds in size the semilunar ganglia of the great sympathetic," and "is nearly two inches in breadth." "The middle vesical ganglion," and "the internal and external vesical ganglia," which "form a great web of ganglia and nerves on the side of the vagina." Dr. LEE further adds, "It is chiefly by the influence of these nerves, that the uterus performs the varied functions of menstruation, conception, and parturition, and it is solely by their means that the whole fabric of the nervous system sympathises with the different morbid affections of the uterus. If the nerves of the uterus could not be demonstrated, its physiology and pathology would be completely inexplicable." In the progress of my dissections, I found that the structure considered by Dr. LEE as "the hypogastric or utero-cervical ganglion" was a mass of dense fibro-cellular tissue enveloping several small ganglia and a nervous plexus, formed at the junction of the lateral hypogastric plexus with branches from the sacral nerves; that the "vesical ganglia" were also a mass of fibro-cellular tissue, in about the centre of which were situated small ganglia; and that the remaining structures described as ganglia and plexuses were not nervous structures.—(May 1846.)

The gravid uterus I had dissected was that of a woman about thirty-five years of age, and of middle stature; and to obviate as much as possible any objection that might be raised on the ground of individual peculiarity, the organ selected for the second dissection was that of a woman about the same age and stature as the former. She had also borne children.

The comparison thus made demonstrated the truth of the former supposition, and clearly showed that the nerves had undergone no change of size during pregnancy, nor of position, except such as resulted from the enlargement of the organ over which they were distributed.

The Great Splanchnic Nerve and Semilunar Ganglion.—The great splanchnic nerve is said to be formed by branches which come from the sixth, seventh, eighth and ninth, and sometimes tenth, thoracic ganglia. These branches, after passing forwards and downwards, unite at the side of the dorsal vertebræ, and constitute the nerve, which after piercing the diaphragm ends in the semilunar ganglion. If the branches said to come from these ganglia be examined, it will be seen that this is only their apparent origin, and that they are branches of the intercostal nerves. The branches of communication between the spinal nerves and the thoracic ganglia consist of two distinct portions, marked by difference in colour, consistency and distribution. One portion, the smaller of the two, is soft, semitransparent, and of a light brown colour. It leaves the posterior border of the thoracic ganglion, and joins the spinal nerve about one-eighth of an inch anterior to the giving off of the white portion; a gray communicating cord also passes between the thoracic ganglia. This ganglionic mass, when first exposed in the recent dissection, was of a deep red-brown colour, which quickly faded to a light brown by the action of the water in which it was examined. The other portion, about one-half larger than the former, is firm, of an opake pearly-white colour; it passes to the anterior surface of the ganglion, and divides into two portions. One of these portions joins with a similar part, sent down from the ganglion next above, and then goes out in a curving direction on the side of the dorsal vertebræ to contribute in the formation of the splanchnic nerve. The other half of this branch of the intercostal nerve turns down, constituting a part of the intercommunicating cord between the ganglia, to the ganglion next below, and there joining with a similar portion from the intercostal nerve on a level with this ganglion, passes forwards to join the other branches which form the splanchnic nerve. Each branch sent to the splanchnic nerve contains branches from at least two intercostal nerves, viz. from the nerve on the level with its apparent origin, and from the nerve next above it. This arrangement of the nervous fibres is very apparent in the recent dissection, from the marked distinction which exists in colour and consistency between the gray and white portions of the so-called trunk of the sympathetic.

The splanchnic nerve formed by the branches of the intercostal nerves is a single round cord, which increases in size on the addition of each branch. About an inch below the junction of the last branch it separates into two parts, and upon one of these a ganglion is formed, similar in appearance to those found on the posterior branches of the spinal nerves. About an inch below this ganglion, the two portions of the splanchnic nerve interchange some fibres which form a small plexus. This plexus terminates in several funiculi, which, surrounded by a common cellular envelope, pierce the diaphragm, and end in a collection of ganglia at the side of the cœliac axis.

This collection of ganglia, when considered collectively, is named the semilunar ganglion, and is described as consisting of six or eight ganglia with cords connecting them together. Yet each of these six or eight ganglia is an aggregation of smaller ganglia. The connecting cords sometimes contain ganglionic corpuscles, but most frequently they are composed of only nervous fibres. Six or seven of the funiculi of the splanchnic nerve end in a common ganglion at the superior and outer corner, and the remaining three pass behind, and, joining with a branch from the lesser splanchnic, end in a ganglion placed anterior to the root of the renal artery. From this collection of cœliac ganglia branches are sent to the viscera in the neighbourhood[*].

[*] Professor CRUVEILHIER, in his Anatomie Déscriptive, vol. iv. p. 1011, says, "Si, sur une pièce qui a macéré dans l'acide nitrique étendu, on cherche à déterminer d'une manière exacte le point le plus élevé de l'origine du grand nerf splanchnique, on verra, d'une part, que les filamens blancs dont la réunion constitue ce nerf, sont déjà distincts au niveau du troisième ganglion thoracique, et, d'une autre part, que ces filamens blancs sont simplement accolés au cordon de communication ainsi qu'aux ganglions, qu'ils se continuent avec les branches émanées des paires rachidiennes; en sorte que l'anatomie de texture démontre de la manière la plus évidente, la continuité du nerf splanchnique avec les paires rachidiennes."

The branches of the spinal nerves which form the white connecting cords with the sympathetic, and which chiefly form the great splanchnic nerve, can be readily traced as high as the third thoracic ganglion. And if the sympathetic be examined in dilute acetic acid, or a solution of bay-salt and arsenite of soda, smaller branches which progressively decrease as we ascend, may be traced from all the superior thoracic ganglia. The branches which form the splanchnic nerve are not exclusively derived from the inter~~spinal~~ costal nerves, but are partly composed of gelatinous nervous fibres derived from the thoracic sympathetic. These gelatinous fibres, although associated with the tubular fibres of the spinal nerves, are yet distinct, and so connected with the thoracic ganglia above and the semilunar ganglion below, as to leave no doubt in my mind that they exist as an independent system of nerves. The gray roots of the sympathetic, as they are called, are branches of the sympathetic given off from the thoracic ganglia, in the same manner as the branches of the sympathetic are given off from the semilunar ganglion. Its composition, as shown by the microscope, is also analogous to that of the branches of the sympathetic nerve, consisting chiefly of gelatinous nervous fibres, with some tubular fibres. It arises from the thoracic ganglion by a single trunk, soon divides, and is chiefly distributed to the vessels: some of the gelatinous fibres join the intercostal nerve, and, becoming associated with other gelatinous fibres which arise from the ganglion on the sensitive root of the spinal nerve, go with the intercostal nerve in its distribution. The ganglia on the sensitive root of the spinal nerves become thus associated with the ganglia of the sympathetic, whose office, anatomically considered, is to give origin to the gelatinous fibre. A few gelatinous fibres are found in both the motor and sensitive roots of the spinal nerves, but the quantity is so small when compared with the quantity found in other parts, as to preclude the idea that the sympathetic arises from them. Most probably these fibres are distributed to the vessels of the cord; as gelatinous fibres, which come from the gray branch of the thoracic ganglion, pass along the motor root in the direction of the spinal cord, and gelatinous fibres, from the same source, also enter the ganglion on the sensitive root; both these sets of fibres evidently pass from the thoracic ganglion towards the spinal cord. We have thus two distinct and separate

The Lesser Splanchnic Nerves.—These nerves having suffered some injury in the removal of the preparation from the body, I cannot decidedly give their origin; but they appear to be derived from the intercostal nerves in the same manner as the greater splanchnic. They are two in number; the superior divides into two branches, one of which joins the ganglion at the root of the renal artery; the other branch divides into three filaments, of which one ends in a ganglion at the side of the aorta, whilst the remaining two end in ganglia on the renal plexus. The inferior splanchnic nerve (posterior renal of Walter) is chiefly distributed to the renal plexus, but sends one branch to the ganglion at the commencement of the aortic plexus.

The Renal Plexus.—The kidney is supplied by about fifteen branches, twelve of which proceed from the outer margin of the semilunar ganglion, and three branches from the ganglion in which the lesser splanchnic nerve ends. These nerves in their course assume a plexiform arrangement, and form several (eight or nine) smaller ganglia varying from the $\frac{1}{10}$th to $\frac{1}{40}$th of an inch in diameter, which appear of the same kind as those previously noticed by Remak in various parts of the sympathetic. Some of the branches from the lesser splanchnic nerves also end in this plexus.

The Nerves of the Supra Renal Capsule.—From the centre of the semilunar ganglion, three branches pass upwards and outwards to this body. Three other small cords are also supplied by the ganglion in which the principal part of the greater splanchnic nerve ends.

The Superior Aortic Plexus.—This plexus (plexus intermesaraicus vel plexus aorticus abdominalis) is situated in front of the aorta, between the cœliac axis and the inferior mesenteric artery. It is formed by four or five branches which proceed from the ganglion before noticed at the root of the renal artery; by two or three branches from the ganglion at the side of the aorta in which part of the lesser splanchnic nerve terminates; and by branches from the superior lumbar ganglia. These branches passing downwards and inwards unite with similar branches from the opposite side, and form a plexus in front of the aorta. Several smaller ganglia are formed in the plexus, some of which are so minute as to measure only $\frac{1}{75}$th of an inch. Minute branches are sent from this plexus towards the aorta, and are lost in its cellular coat,

systems of nerves; one composed of gelatinous nervous fibres which have their origin at the different ganglia; the other composed of tubular nervous fibres which arise at the brain and spinal cord; for notwithstanding the opposite opinion held by Volkmann and Bidder, founded as it is upon very careful and elaborate investigations, I have assured myself, that the tubular fibres, which are mixed with the gelatinous in the gray cords of the sympathetic, are really derived from the cerebro-spinal nerves, and do not originate in the ganglia. The claim of the gelatinous fibres to be considered true nervous fibres is further shown, by many small nerves being entirely composed of them, and by the ultimate distribution of many of them to the arteries. The so-called white roots of the sympathetic are then branches of the spinal nerves, and are distributed to the viscera; and the so-called gray roots, branches of the sympathetic, which passed from the thoracic ganglia, and are distributed to the vessels in the neighbourhood. These facts were demonstrated by preparations at the time this paper was presented to the Society, but in consequence of their differing from the received opinions upon the subject, I was diffident of having drawings made from the preparations. The drawings, with their accompanying explanations, will be presented in a supplementary paper.—(May 1846.)

but being so fine it was impossible to trace them further, or to preserve them in the dissection. They measure $\frac{1}{500}$th of an inch in diameter.

The Ganglia at the Root of the Inferior Mesenteric Artery.—These ganglia, after receiving the terminal branches from the superior aortic plexus and branches from the three lumbar ganglia, furnish the nerves accompanying the inferior mesenteric and superior hæmorrhoidal arteries, and send from their lower border branches which form the inferior aortic plexus. The branches supplied by the lumbar ganglia are branches of the spinal nerves, derived in the same manner as those constituting the greater splanchnic nerve. These branches pass over the lumbar ganglia, and becoming associated with gelatinous fibres, end in the ganglia at the root of the inferior mesenteric artery; in the same way as the branches passing over the thoracic ganglia, form the splanchnic nerve, and end in the semilunar ganglion.

The Inferior Aortic Plexus.—The plexus, which forms a continuous plexiform arrangement extending from the root of the inferior mesenteric artery to its division into the lateral hypogastric plexus, below the bifurcation of the aorta, has been variously named: it has been called by VALENTIN *Plexus divisionis aortæ superior et inferior*; and the portion below the bifurcation of the aorta has been called by TIEDEMANN *Plexus hypogastricus magnus superior, vel uterinus communis.* It is formed by twelve or fourteen branches, which proceed from the inferior borders of the ganglia at the root of the inferior mesenteric artery, and passing inwards, unite with similar branches from the opposite side, and form a plexus in front of the aorta. The plexus has no distinct ganglia in its course, nor has it any marked division, but at the bifurcation of the aorta six or seven filaments are sent along the common iliac artery. Some of these accompany the internal iliac artery, and join the pelvic plexus at the side of the vagina, whilst one branch joins the third sacral nerve midway between the third sacral foramen and the sacral plexus. The remainder of the nerves which pass along the common iliac artery from the aortic plexus accompany the external iliac artery.

The inferior aortic plexus, an inch and a half below the bifurcation of the aorta, divides into the two lateral hypogastric plexuses, where a few crossing fibres occur. These crossing fibres are surrounded in this exposed situation by a dense cellulo-fibrous covering, forming a mass which has been figured and described as a triangular ganglion of a dense and firm structure. Only a small ganglion however exists in this situation.

Lateral Hypogastric Plexus.—It is difficult to ascertain what portion of this plexus Professor TIEDEMANN understood by the plexus hypogastricus lateralis, vel uterinus superior, but probably it was the middle portion, where he has figured it joined by the branches from the sacral ganglia. The plexus extends from the division of the inferior aortic plexus, to the junction of the branches from the sacral nerves at the side of the vagina, and forms a lengthened plexus, situated on the side of the pelvis. Like the inferior aortic plexus it forms no large ganglia in its course; but the nerves which compose it several times unite and again separate, and at each point of junction a distinct swelling or knot is perceived, which contains ganglionic corpuscles lying by the side of the interlaced nervous fibres, though in too small a quantity to produce the usual red appearance of ganglia. A few branches of communication pass between this plexus and the branches accompanying the superior hæmorrhoidal artery.

The Pelvic Plexus.—The union of the branches from the lower part of the lateral hypogastric plexus, with branches from the sacral plexus, constitutes a plexus so peculiar and distinct that I have ventured to propose the name *Pelvic Plexus* for it. It furnishes branches of supply to the bladder, vagina, and rectum, and corresponds with the plexus hypogastricus lateralis, vel plexus uterinus inferior, vel plexus gangliosus, of TIEDEMANN. Twelve or thirteen branches are given off from the third sacral nerve, five or six from the fourth, and one from the second, which passing to the side of the vagina join the short branches which descend from the lateral hypogastric, and the branches which descend with the superior hæmorrhoidal artery, and constitute a plexus. At the points of union between the branches from the sacral nerves, and the branches from the hypogastric, small ganglia generally exist. Several smaller secondary ganglia are also formed in the plexus. The ganglia in this situation are much smaller than those at the root of the superior hæmorrhoidal artery, and the nerves which go to the bladder and vagina contain a much larger amount of tubular nervous fibres than those which proceed to the uterus, the rectum, the intestines, &c.

The Nerves of the Bladder.—From the anterior part of the pelvic plexus, branches of considerable size are sent to the bladder, which at first pass amongst the vessels of this part, but do not continue with them in their distribution on the organ. A few minute ganglia are found in their course.

The Nerves of the Vaginal Erectile Tissue.—From the lower part of the pelvic plexus ten or twelve branches descend to the erectile tissue, situated at the lower and anterior part of the vagina. These nerves are joined by five or six branches, which come directly from the third and fourth sacral nerves, and at the junction of the branches from these two sources, small yet distinct ganglia, seven or eight in number, are formed, from which nerves are sent to the erectile tissue. The branches supplied by the sacral nerves course along the posterior border of the pelvic plexus, but do not communicate with it.

The Hæmorrhoidal Nerves.—The rectum is supplied by minute filaments which come from the posterior border of the pelvic plexus, and accompany for the most part the branches of the hæmorrhoidal artery. They, however, are not the direct continuation of those nerves which accompany the superior hæmorrhoidal artery, for these end in the posterior border of the pelvic plexus.

The analogy which exists between the different collections of Ganglia.—From the foregoing facts it will appear that a great analogy exists between the collections of ganglia at the cœliac axis, at the superior hæmorrhoidal artery, and at the pelvic plexus. The same elements exist in each, viz. tubular nervous fibres derived from the spinal cord, and gelatinous nervous fibres derived from the ganglia; the size of the ganglia being in apparent relation to the quantity of gelatinous fibres required for the nerves distributed from these points. The constitution of the nerves which come from these ganglia differs according to the size of the ganglia. Those distributed to the bladder and vagina differ from the nerves sent to the uterus, intestines, &c., in containing a much larger amount of tubular nervous fibre*.

Nerves of the Unimpregnated Uterus.—The nerves which compose the hypogastric plexus, on approaching the neck of the uterus, begin to separate, having larger spaces between them, and on a level with the os uteri they are joined by the branches already described, which accompany the superior hæmorrhoidal artery. This expansion appears to be only the spreading out of the posterior portion of the hypogastric and not of the anterior portion; for the latter, after being joined by the branches which accompany the iliac arteries, passes directly onwards by the broad ligament and supplies the lower half of the uterus. These nerves, or it may be said these continuations from the anterior part of the lateral hypogastric plexus, pass towards the uterus, and mixing with the arteries of this part, go on in company with them for some part of their course, but as they approach the body of the organ they separate, and each pursues a separate distribution. As the nerves approach the uterus they lose the plexiform character, and form a number of delicate branches, which pass on as distinct fine cords, dividing and subdividing, but not uniting with each other. For the supply of the middle part of the uterus a distinct branch comes from the inferior aortic plexus, and running down by the side of the pelvis, receives no communication from the hypogastric, but passes directly to the superior part of the body of the uterus. It there divides, supplying the portion between the insertion of the Fallopian tubes and the termination of the previous branches. It also sends a branch to the ovary. The fundus of the uterus, or the portion above the Fallopian tubes, is sometimes supplied by a branch from the nerves furnished to the ovaries, as seen in the dissection of the gravid uterus.

Distinct from these nerves is another set, which comes from the same continuation of the hypogastric plexus, but assumes a plexiform arrangement round the vessels, and has the distinctive character of forming minute ganglia here and there. These nerves are so minute, that a special dissection is required to determine their ultimate distribution, although their arrangement would lead to the inference that they were especially destined for the vessels. Before the nerves were cleared from their neurilema, I frequently met with what appeared to be nervous branches distributed to the arteries, but in every instance I have been able, by the aid of the microscope, satisfactorily to ascertain that these were minute vessels passing from the artery to the nerve to ramify in its neurilema, and not branches of the nerve going to the artery. This was proved by their elasticity, by the absence of transverse striæ, and by the mode of distribution; for they ended abruptly at the artery by a single large termination, whilst they divided and branched to the nerve. It was proved, moreover, by their presenting when divided the opening of a distinct yet small tube, from which air escaped when blown into the artery. I have been unsuccessful in tracing large branches of nerve to the ureter, though I have carefully examined many which in the first instance appeared to be nerves; but all of which proved to be small vessels or rounded cords of fibrous tissue, with the exception of one small filament, which came from the anterior margin of the hypogastric plexus after its junction with the branches which accompany the internal iliac artery, and passing upwards to the ureter, divided and apparently supplied it. From the delicacy of this filament and its position in the dissection it was impossible to preserve it.

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* The sole anatomical purpose of the ganglia is apparently to give origin to the gelatinous fibres, to which end they are distributed irregularly over the body, in those situations where a supply of the gelatinous fibre is required. The true sympathetic system appears to be a system of gelatinous nervous fibres, which are distributed everywhere over the body, and which preside over the organic functions. It appears to exist independently of the brain or spinal cord, although the tubular fibres which come from the brain and spinal cord are associated with the gelatinous fibres in the larger branches of the sympathetic. In the minute branches the gelatinous fibres exist, separate and distinct from the tubular, and are distributed to the arteries. They may however have other distributions; but this, together with the ultimate distribution of the tubular fibre, remains for future inquiry.—(May 1846.)

The Fallopian tube is supplied by a branch which passes off from the anterior border of the hypogastric plexus a little above the level of the os uteri, and, entering the broad ligament, receives two branches from the nerves which accompany the internal iliac artery, and branches from the nerves between the bladder and uterus. It then passes up to supply the Fallopian tube. The branches derived from the nerves between the bladder and uterus were accidentally divided in an early part of the dissection, hence I am unable to speak decidedly from what source they came. That they were branches of augmentation and not of division, is shown by the trunk of the nerve being enlarged after each junction.

The Vessels of the Uterus.—When the vessels of the uterus are divided transversely, they present a wavy outline at the inner border of the section, and when opened longitudinally, the inner surface presents a number of folds, resembling the rugæ of the internal surface of the stomach or bladder when contracted. From these appearances, in which the internal and middle coats of the artery are involved, I am inclined to think that the vessels do not diminish in size after parturition, but are only contracted in their cavity, ready to be again stretched out upon a larger quantity of blood being sent to the organ. This point however remains for further examination, as also the change which occurs during the first pregnancy, in which we would, *à priori*, suppose that the vessels do increase in size.

The Nerves of the Gravid Uterus.—After the description of the nerves of the unimpregnated uterus, it is only necessary to mention that the nerves of the gravid uterus follow the same course and distribution in all material respects. They however differ in two slight points. 1st. In consequence of the increased size of the parts, the pelvic plexus and the inferior part of the hypogastric plexus are extended over a larger surface, which allows their arrangement to be more readily determined. The continuation of the hypogastric plexus, which supplies the uterus, is seen to approach the side of that organ in company with the vessels, and afterwards to leave them, some of the branches passing to the anterior, and some to the posterior surface, both of which finally enter into its substance. 2ndly. The course taken by the nerve which supplies the middle portion of the uterus appears to be different in the two dissections. This however is more apparent than real, for the nerve passes off from the hypogastric plexus high up in the pelvis, and coming down in company with it interchanges some filaments. On reaching the neck of the uterus it enters the organ, and passing up in a distinct tendinous canal immediately beneath the surface, neither receives nor gives any branches until it reaches the portion a little below the insertion of the Fallopian tubes; there the tendinous canal ceases, and the nerve divides into two branches, one supplying the anterior, and the other the posterior surface. The anterior branch, the larger of the two, after entering deeply into the substance of the uterus, again approaches the surface at the insertion of the Fallopian tube, and apparently sends some filaments to it; but whether this is the case or not I am unable to decide, as the nerve was accidentally divided.

The Nerves of the Ovary.—The nerve supplying the ovary passes down from the renal plexus in company with the spermatic artery, and when about two and a half inches from the gland it separates from the artery, taking a slightly different course to reach the middle of this body. It there divides into four branches, of which three supply the ovary, and the fourth, passing onwards to the uterus, again divides into two branches, which enter the substance of the uterus on the anterior and posterior aspect of the fundus. Before the nerve reaches the ovary to divide into its terminal branches, it forms a considerable fusiform enlargement.

The Size of the Nerves.—The size of the nerves in both these dissections is essentially the same, and when the nerves are carefully compared, no doubt is left that the nerves of the gravid uterus have undergone no change in size; nor any change in position, except that consequent upon the development of the organ. Yet at first sight the nerves of the unimpregnated uterus appear even larger than those of the gravid uterus; this however is due to the manner in which they are arranged. In the unimpregnated state of the uterus, the nerves of the lower portion of the hypogastric and pelvic plexuses, are crowded and packed together so as to occupy a much smaller space than they do in the gravid state of the uterus. The consequence of this is, that the nerves of the former present a wavy arrangement, which gives them the appearance of greater thickness and plumpness. The close manner in which they are packed, and the wavy aspect they assume, can only be fully appreciated when they are first exposed; for in the after process of cleaning and isolating them from the surrounding tissues, these characters are considerably altered.

We may therefore conclude—

1. That the uterus receives its nerves from the hypogastric plexus. It ought

however to be mentioned that some have considered, on physiological grounds, that small branches derived from the sacral nerves, after their union with the pelvic plexus, might reach the neck of the uterus by a circuitous route; but this appears contrary to anatomical evidence.

2. That the ovaries are supplied by branches derived from the renal or aortic plexuses.

3. That the Fallopian tubes are supplied from the hypogastric and aortic plexuses, though it is probable they also receive some branches from the nerves at the superior part of the bladder.

4. That the bladder and vagina are supplied by branches from the pelvic plexus, which contain a large amount of tubular nervous fibres derived from the sacral nerves.

5. That the rectum also receives its nerves from the pelvic plexus, but they on the contrary contain a small amount of tubular fibres.

6. That the nerves undergo no change during a second pregnancy.

7. That it is probable the vessels do not decrease in size after parturition, but are only contracted in their cavity.

Important however as these conclusions are, there yet remain several points which require further investigation; for instance,—

1. Whether any and what change takes place in the nerves at the first pregnancy*. For although it is clear no material difference exists between the nerves of the two preparations described, yet it must not be forgotten that both women had previously borne children.

2. Whether any and what change takes place at puberty.

3. The condition of the vessels in a first conception and their subsequent state.

4. In what consists the great enlargement of size in the gravid uterus.

5. Is there any difference in the composition of the nerves distributed to the ovaries and Fallopian tubes, as compared with those sent to the uterus?

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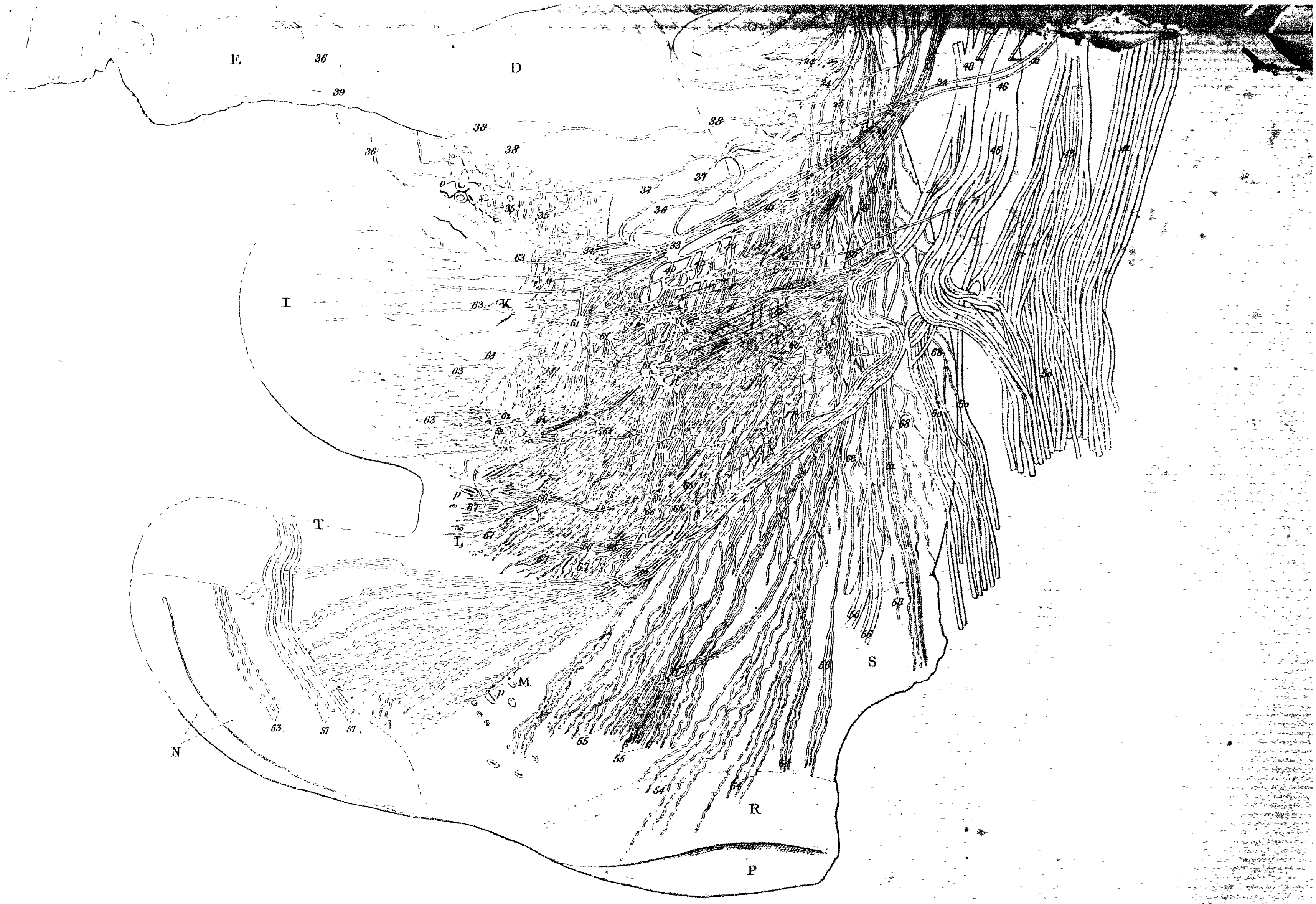
* I have recently had an opportunity of making a cursory examination of the nerves of a virgin uterus, and find they do not differ in size from the nerves of the gravid uterus previously described. Time has not permitted me to carry the examination so far as to determine, whether or not the nerves undergo any increase in length in a first pregnancy.—(June 18, 1846.)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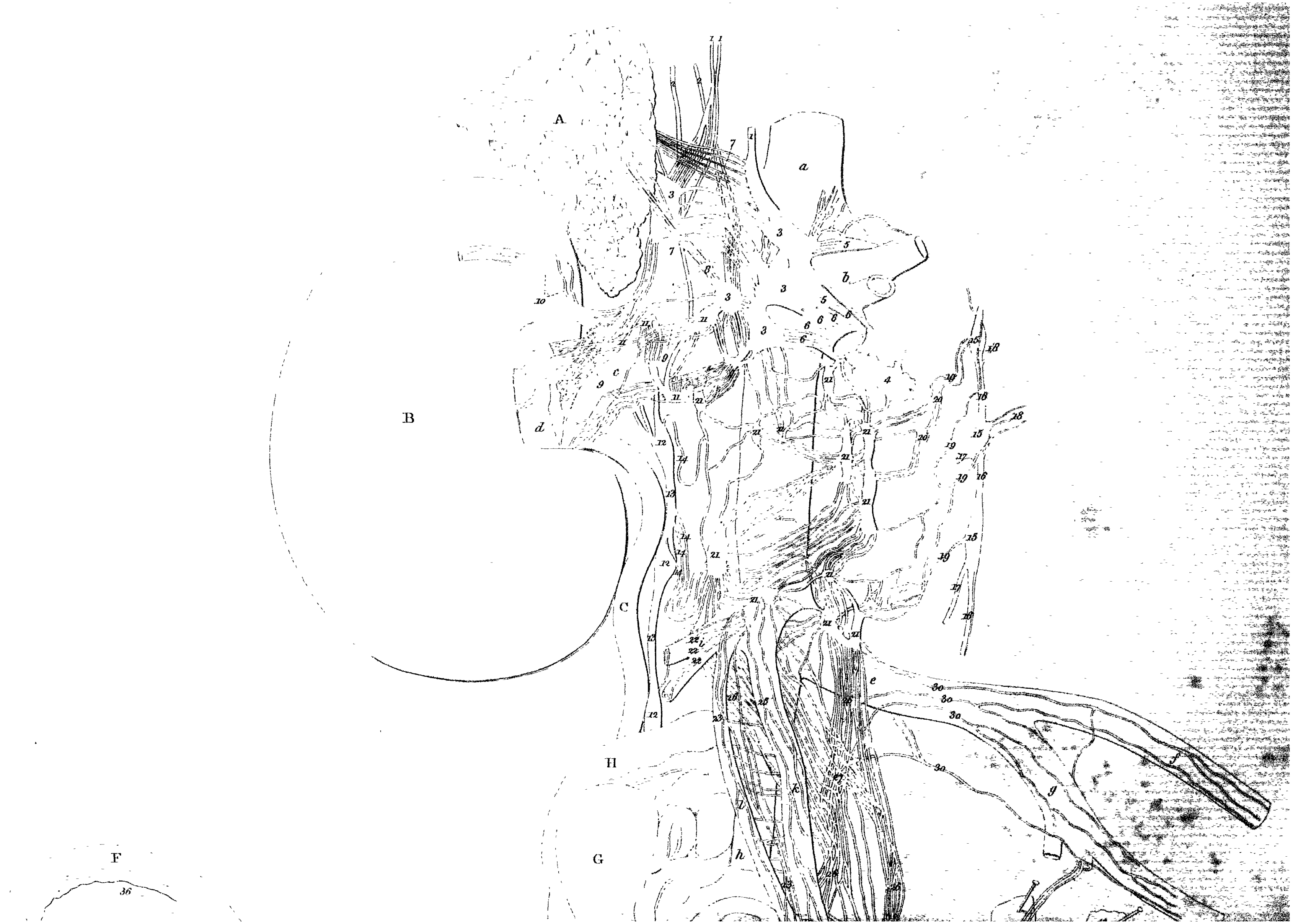
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On the Nerves of the Uterus. *By* THOMAS SNOW BECK, *Esq.*

DESCRIPTION OF THE PLATES*.

Received July 6, 1846.

PLATE XII.

A.	The supra renal capsule.
B.	The right kidney.
C.	The right ureter.
D.	The uterus.
E.	The left ovary.
F.	The left Fallopian tube.
G.	The right ovary.
H.	The right Fallopian tube.
I.	The bladder.
K.	The opening of the divided left ureter.
L.	The erectile tissue at the lower and anterior part of the vagina.
M.	The vagina.
N.	The labia majora.
O.	The superior part of the rectum.
P.	The anus.
R.	The sphincter ani.
S.	Some fibres of the levator ani.
T.	The clitoris.

a.	The abdominal aorta.
b.	The cœliac axis.
c.	The renal artery.
d.	The renal vein.
e.	The left common iliac artery.
f.	The left external iliac artery.
g.	The left internal iliac artery.
h.	The right common iliac artery.
i.	The inferior mesenteric artery.
k.	The superior hæmorrhoidal artery.
l.	A variety of the superior hæmorrhoidal artery which anastomoses with the other trunk of the same artery.
m.	The point where the two trunks of the superior hæmorrhoidal artery anastomose.
o.	The divided uterine vessels, arteries and veins.
p.p.p.	The openings of divided arteries.

1.1.1. The terminal funiculi of the great splanchnic nerve, which are each composed of definite proportions of tubular and gelatinous fibres. The great splanchnic nerve is, essentially, the union of the visceral branches from all the superior intercostal nerves, which are associated with each other in their course to the semilunar ganglion. The branches from the first, second, third, fourth, and fifth intercostal nerves turn down in the so-called trunk of the sympathetic, and after uniting with each other, pass from the trunk of the sympathetic opposite the sixth intercostal nerve, as a large and single branch. The branch from the sixth intercostal nerve turns down in the trunk of the sympathetic, and leaves it opposite the seventh intercostal nerve. The branches from the seventh, eighth, and sometimes ninth intercostal nerves follow a similar course. Each of these visceral branches of the intercostal nerves becomes associated with a portion of gelatinous fibres, as it passes over the thoracic ganglion of the sympathetic, on a level with the nerve from which the branch arises. Thus the splanchnic nerve, although essentially composed of tubular fibres derived from the cerebro-spinal nerves, has in its formation a portion of gelatinous fibres derived from each of the thoracic ganglia. These two kinds of fibres, *i. e.* the tubular fibres and the gelatinous fibres, although associated together, are yet as distinct as the motor and sensitive tubules of the cerebro-spinal nerves, after they are mixed with each other; for by spreading out the tubules of the splanchnic nerve, each set of fibres can be distinctly and separately traced to its origin and termination. In the course of the gelatinous fibres down the splanchnic nerve, some ganglia are always to be found; sometimes one, when it is comparatively large; sometimes as many as three, when they are small and may be readily overlooked. Were it necessary to offer any confirmation to the fact, that the gelatinous fibres arise in the ganglia of the sympathetic, these ganglia on the splanchnic nerve would offer a ready and convenient demonstration; for by comparing the fibres which enter at their upper part with the fibres which pass out at their lower part, the latter are found considerably to exceed the former. The splanchnic nerve usually exists as a single round cord, having a ganglion at the lower part; but occasionally we find it divided into two very distinct parts, one white and the other gray. In this instance the white part is chiefly composed of the tubular fibres, to which it owes its white aspect, yet it contains a small portion of gelatinous fibres; and in like manner, the gray part, although consisting chiefly of gelatinous fibres, which give it the gray appearance, contains some tubular fibres. Although an interlacing of the tubular and gelatinous fibres occurs in the whole course of the splanchnic nerve, yet it takes place chiefly at the lower part below the ganglion. The apparent object of this interlacing is the due proportioning of the tubular and gelatinous fibres, which is found in the distinct funiculi, in which the splanchnic nerve terminates. The gelatinous fibres of the splanchnic nerve enter the gray portion of the semilunar ganglion; and although I have been unable to trace them further, yet I do not think they end there; for in the sympathetic ganglia, which are so minute as to allow their structure to be examined, without previous dissection of them, the nervous fibres which constitute the nerve upon which the ganglion is formed, all pass beyond the ganglion, after being joined by other gelatinous fibres, which come from the ganglionic corpuscles of which the minute ganglion is composed. The tubular fibres of the splanchnic nerve enter the semilunar ganglion, and after spreading out in its different lobes, pass through it, and are found in the branches of the sympathetic which proceed from the ganglion. Although the semilunar ganglion, from its size and complex formation, is not well adapted for deciding a minute anatomical point, yet I have, by repeated and careful examination, assured myself that the tubular fibres which are found in the sympathetic branches proceeding from it, are all derived from the cerebro-spinal nerves, through the medium of the splanchnic nerve; and that none of the tubular fibres arise from the semilunar ganglion. Notwithstanding the contrary opinion held by some most distinguished anatomists, viz. that some tubular fibres arise from the sympathetic ganglia, I have, by examination of various parts of the sympathetic, assured myself that the tubular fibres can, in every instance, be traced to the white connecting cord between the spinal and sympathetic nerves; which white connecting cord is a branch from the spinal nerve with which it is connected.

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* This description was necessarily delayed until the Plates were lettered.—T. S. B.

2.2. The lower portions of the lesser splanchnic nerves. They are composed of gelatinous fibres, and tubular fibres, in the same manner as the great splanchnic nerve (1.1). The gelatinous fibres arise from the lower thoracic ganglia of the sympathetic, and passing inwards, are given partly to the renal plexus (9.9), and partly to the superior aortic plexus (21.21, &c.). The tubular fibres are visceral branches of the lower intercostal nerves, and after passing down the trunk of the sympathetic to opposite the nerve next below it, pass inwards, in company with the gelatinous fibres, towards the semilunar ganglion. Some of the tubular fibres turn outwards, and entering the renal plexus (9.9), they are distributed to the kidney; the remainder enter the superior aortic plexus (21.21, &c.), and chiefly pass off at the root of the inferior mesenteric artery (*i*) in the branches of the sympathetic sent from this point.

3.3.3.3.3. The lobes of the right semilunar ganglion, which, in this instance, are much separated from each other. If we restrict the term ganglion to a collection of ganglionic corpuscles, giving rise to the gelatinous fibre, which collection is distinct from another similar collection of corpuscles lying by the side of it, the two being separated by tubular fibres and blood-vessels, then these lobes are an aggregation of distinct ganglia. The tubular fibres of the splanchnic nerves pass through this ganglion and become associated with the gelatinous fibres which arise from it. The association of the gelatinous and tubular fibres constitutes the ordinary branches of the sympathetic.

4. A portion of the left semilunar ganglion.

5.5. Nervous branches which pass between the two semilunar ganglia. I am inclined to think that a crossing of fibres between the two ganglia takes place in this situation.

6.6.6.6.6. Branches of the sympathetic, which pass out with the cœliac axis (*b*), and are distributed to the liver, pancreas, small intestines, stomach, &c. The branches of the sympathetic, of sufficient size to be seen by the unassisted eye, are composed of many gelatinous fibres associated with some tubular fibres; but in the fine divisions of these nerves, small branches are found entirely composed of gelatinous fibres; and if these small branches be further traced, single gelatinous fibres are seen to pass from them, and to enter the cellular coat of small arteries; and finally, to pass along by the side of the artery, taking a slightly winding course round the vessel, and lying upon the middle coat. The origin and subsequent interlacing of the tubular and gelatinous fibres is better seen in the small branches which pass from the posterior part of the thoracic ganglia. These branches, from their small size, can be examined by the compound microscope without any previous manipulation. At their origin from the ganglion, the tubular and gelatinous fibres are in distinct and separate bundles; and after proceeding a short distance, the fibres composing the two bundles gradually spread out and become interlaced with each other. In some instances, where the small branch bifurcates soon after it leaves the ganglion, the tubular fibres, composing the tubular bundle, divide into two portions, which pass out in the two minute branches in which the small parent branch divides; the gelatinous fibres, composing the gelatinous bundle, likewise divide into two portions, which also pass out in the two minute branches and become mixed with the tubular fibres. The crossing of the gelatinous and tubular fibres in the parent trunk to gain their ultimate destination, is exceedingly well-marked. If the fibres composing these small branches be followed towards the so-called trunk of the sympathetic, we find that the gelatinous fibres take their origin at the corpuscles of the ganglion, and that the tubular fibres are traced through the ganglion to the white cord connecting the spinal and sympathetic nerves. In this case, as in the preceding one, the tubular fibres do not arise from the ganglion, but can be shown to be emanations from the spinal nerves. The origin of these small branches by distinct bundles of gelatinous and tubular fibres, and their subsequent interlacing, bear a striking resemblance to the origin of the spinal nerves, by distinct bundles of motor and sensitive tubules, and their subsequent interlacing.

7.7. Branches of the sympathetic distributed to the supra-renal capsule from the semilunar ganglion.

8. Small ganglion on these nerves.

9.9. The renal plexus surrounding the renal artery.

10. Branches from the renal plexus which accompany a branch of the renal artery to the upper part of the kidney.

11.11.11.11. Ganglia in the course of the renal plexus. Besides these ganglia, there are many much smaller which could not be shown in this drawing, some of which are so minute as to measure but the $\frac{1}{40}$th of an inch in diameter. The gelatinous fibres of the renal plexus are chiefly derived from the semilunar ganglion (3.3.3), though many arise from the ganglia in the plexus (11.11, &c.). The tubular fibres are derived from the lower intercostal nerves through the medium of the lesser splanchnic nerves (2.2).

12.12.12. The ganglia of the abdominal sympathetic of the right side.

13.13. The so-called trunk of the sympathetic of the right side.

14.14.14.14. Branches which pass from the lumbar nerves and trunk of the sympathetic, and enter the superior aortic plexus (21.21.21, &c.).

15.15.15. Three ganglia of the abdominal sympathetic of the left side.

16.16.16. The so-called trunk of the abdominal sympathetic of the left side.

17.17. Two of the so-called gray roots of the sympathetic, which, in consequence of lying loose in the preparation, have been turned in the wrong direction by the artist. These branches, which have often been erroneously considered roots of the sympathetic, pass from the posterior part of the lumbar ganglia, and sending some branches to the vessels in the immediate neighbourhood, join the lumbar nerves. The composition of these branches, as shown by the compound microscope, is analogous to the usual branches of the sympathetic, being formed of many gelatinous fibres, mixed with some tubular fibres. The gelatinous fibres are derived partly from the ganglion from which a branch passes, and partly from the ganglion next above, which latter portion turns down in the cord communicating between the ganglia and then passes out in the branch. The tubular fibres are derived in a similar manner, *i. e.* from the white cord connecting the spinal and sympathetic nerves, which is on the level of the ganglion from which a branch arises, and from the white cord next above. The latter portion turns down in the cord communicating between the ganglia, and passes through the upper part of the ganglion to reach the branch; the former portion leaves the white cord immediately it reaches the ganglion, and turning backwards enters the branch. In this instance, as in the preceding ones, the tubular fibres can be shown to be emanations from the spinal nerves, although they pass through the ganglia in the course of their distribution. The process of tracing these tubular fibres is exceedingly tedious and difficult, yet it can be done; and I have best succeeded by employing the solution of bay salt and arsenite of soda, which, whilst it gives sufficient firmness to the nervous tubules, alters their natural appearance much less than spirit and water. After giving some branches to the lumbar arteries, a portion of the branch joins the lumbar nerves and divides into two parts, one of which passes backwards in the direction of the spinal cord, and the other becomes associated with the gelatinous fibres arising from the ganglion on the sensitive root of the nerve, and passes out in the distributions of the lumbar nerve.

18.18. Two of the white cords connecting the spinal and sympathetic nerves, which have been often erroneously considered roots of the sympathetic. By following the tubular fibres which compose these cords back towards the spinal cord, we find them to be derived from the motor and sensitive roots of the nerve, in apparently equal proportions. And by following the same tubular fibres in the direction of the sympathetic ganglion, we find that on arriving at the ganglion they take several directions. 1. Some turn backwards and enter the gray branch, previously noticed, which passes from the posterior part of the ganglion. 2. Some penetrate the ganglion and enter into the small branches which proceed from the under surface of this body. 3. Some turn down in the so-called trunk of the sympathetic, and supply the tubular fibres found in the different branches which proceed from it; and 4, some, and these by far the most numerous, pass inwards and join the lower part of the superior aortic plexus (21.21, &c.). The last set of tubular fibres becomes apparently attached to the ganglion on passing over it; but this is caused by gelatinous fibres, which arise from the ganglion, becoming associated with the tubular fibres, and passing with them to the lower part of the superior aortic plexus (21.21, &c.). Sometimes the tubular fibres and gelatinous fibres remain distinct from each other in the whole course of these last-named branches, so that we have a nerve whose upper half is white and whose lower half is gray. These branches, moreover, have a precisely similar constitution to that of the splanchnic nerves in the thorax, and might, not inappropriately, be termed abdominal splanchnic nerves. The two communicating branches between the spinal and sympathetic nerves are differently arranged in the thorax, in the abdomen, and in the pelvis. In the thorax, the branches are of nearly equal size through the whole extent of the cavity. In the abdomen, however, the gray branch is much larger than the analogous branch in the thorax, and gradually increases in size to the lower part of the abdomen. The white branch, on the contrary, is smaller than the corresponding branch in the thorax, and decreases in size towards the pelvis. In the pelvis there is no white branch joining the ganglion; and the branches of the sacral nerves, which might be said to represent it, pass over the sacral ganglia without being at all connected with them, and end in the pelvic plexus. The gray branch, on the contrary, is still further increased in size in the sacral region, and after giving some small branches to the vessels near its course, joins the sacral nerves. The tubular fibres found in this portion of the sympathetic, and in the branches which arise from it, are derived from the tubular fibres of the white branch from the lumbar nerves, which fibres turn down in the trunk of the sympathetic, and becoming associated with the gelatinous fibres form the usual sympathetic branches. This arrangement in the human subject corresponds with that described by VOLKMAN and BIDDER in the Frog*.

19.19.19.19. Branches which pass from the abdominal sympathetic to the superior aortic plexus. They are composed of, part tubular, and part gelatinous fibres, in the same manner as the splanchnic nerves in the thorax (1.1. and 2.2). The tubular fibres are derived from the lumbar nerves, and the gelatinous fibres from the abdominal sympathetic ganglia. The purpose of these branches is, moreover, similar to that of the splanchnic, viz. to furnish the tubular fibres which are found in the branches of the sympathetic.

20.20. Small ganglia formed on these branches.

21.21.21.21.21.21.21.21.21.21.21.21. Ganglia in the superior aortic plexus. The branches proceeding from the semilunar ganglion (3.3.3) to the upper part of this plexus are small, and few in number, and appear merely to preserve the general connexion which exists between different parts of the sympathetic. But the branches at the lower part of the plexus are much larger, and much more numerous, and are formed by the gelatinous fibres which arise from the lumbar ganglia (15.15.15), and from the different ganglia in the plexus (21.21.21, &c.), associated with the tubular fibres, derived from the lumbar nerves, through the medium of, what might be called, the abdominal splanchnic nerves (19.19, &c., and 14.14, &c.). The branches of the lower part of this plexus all converge to one point, viz. the root of the inferior mesenteric artery (*i*), where the association of the gelatinous and tubular fibres occurs, previous to the branches being given off to the large intestines, and to the inferior aortic plexus. From the exact similarity which exists between the semilunar ganglion and the inferior part of the superior aortic plexus, in their formation and constitution, it would not be stretching analogy too far to say, that a second semilunar ganglion exists in this situation, having its elements more apart, and being diffused over a larger space. Indeed these aortic ganglia (21.21, &c.) offer a good demonstration of the formation of the more dense structure of the semilunar ganglion (3.3, &c.). The elements of the semilunar ganglion are, the tubular fibres derived from the intercostal nerves, through the medium of the splanchnic nerves (1.1. and 2.2), and the gelatinous fibres derived from the sympathetic ganglia. And the reason of so large an amount of nervous matter being collected in this situation is, no doubt, from its being a common point whence large and numerous branches pass off to the different viscera. The elements which enter into the formation of the lower part of the superior aortic plexus are exactly similar to those which form the semilunar ganglion; viz. tubular fibres derived from the lumbar nerves through the medium of the abdominal splanchnic nerves (19.19, &c., 14.14, &c.), and gelatinous fibres from the sympathetic ganglia (21.21, &c., 15.15). And the reason why a smaller amount of nervous matter exists here than at the semilunar ganglion is, that the branches which pass from it are much less numerous. However, in estimating the branches which pass from this point, we must take into account not only those which pass out with the inferior mesenteric (*i*) and superior hæmorrhoidal (*k*) arteries, but also the branches which form the inferior aortic plexus (22.22); for this latter plexus is constituted in a manner very different from the superior aortic plexus. Whilst the superior aortic plexus may be said to form a plexus distinct in itself, in which the tubular and gelatinous fibres become associated together to form the branches of the sympathetic, the inferior aortic plexus is merely the continuation downwards of some of these branches, so formed, previous to their dividing to form the two lateral hypogastric plexuses.

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* Die Selbständigkeit des Sympathischen Nervensystems, tab. 3.

22.22.22. Branches of the sympathetic which accompany the inferior mesenteric artery (*i*).

23.23.23. Branches of the sympathetic which accompany the superior hæmorrhoidal artery (*k*, *l*). They proceed from a common point with the preceding branches (22.22), and like them are composed of gelatinous and tubular fibres.

24.24. Branches which accompany the divisions of the superior hæmorrhoidal artery, before the formation of the pelvic plexus (61.61, &c.).

25.25. Branches which pass downwards and join the posterior part of the pelvic plexus (61.61, &c.).

26.26.26.26. The inferior aortic plexus, consisting of branches of the sympathetic which pass downwards to form the two lateral hypogastric plexuses (29.29). In the middle of this plexus (27) a crossing of the fibres from the opposite sides occurs, by which means the lower part of the plexus, and, as a consequence, the hypogastric plexus of each side, contains nervous fibres derived from both sides of the body; that is to say, if the nervous fibres composing the left hypogastric plexus be followed upwards, a part of them will be traced to the aortic ganglia (21.21, &c.) and lumbar nerves (19.19, &c.) of the left side, and a part to the aortic ganglia (21.21, &c.) and lumbar nerves (14.14, &c.) of the right side.

28. Small ganglion at the termination of the inferior aortic plexus.

29.29. The lateral hypogastric plexus of the left side, which is composed of gelatinous and tubular fibres derived from the lower part of the superior aortic plexus. It supplies the lower half of the uterus, and sends short branches downwards to join the pelvic plexus (61.61, &c.).

30.30.30.30. Fine sympathetic branches which proceed from the inferior aortic plexus and accompany the iliac arteries (*f* and *g*). Three branches chiefly come from the middle of the inferior aortic plexus (27), where the crossing of the fibres from opposite sides occurs.

31. A branch composed of some of the preceding branches (30.30, &c.), which passes in the broad ligament of the uterus to join the lower part of the lateral hypogastric plexus (22.29).

32. A branch composed of some of the preceding branches (30.30, &c.), which also passes down in the broad ligament and joins the nerve (36) distributed to the upper part of the uterus and Fallopian tube. Like the preceding branch (31), it is drawn out of its relative situation by the position of the preparation.

33. Ganglion at the lower part of the lateral hypogastric plexus.

34. The continuation of the lateral hypogastric plexus (29.29) which supplies the lower half of the uterus.

35.35. Nerves distributed to the lower part of the uterus. These nerves are chiefly composed of gelatinous nervous fibres, which fibres form the chief part of the nerves supplied to the uterus. Although some tubular fibres accompany the gelatinous fibres from the hypogastric plexus, and are found in the uterine nerves, yet they are few in number, and appear to be far from forming the essential element of the nerves supplied to this organ. It remains for further inquiry to determine the element of the uterus to which these tubular fibres are distributed, and the function they perform.

36.36.36.36. A branch which proceeds from the lower part of the lateral hypogastric plexus, is joined by a branch (32) from the inferior aortic plexus (26.26), and by two branches (37.37) which come from the nerves between the bladder and uterus. The nerve after the junction of each branch is increased in size, and passes up in the broad ligament to supply the upper part of the uterus (D) and the Fallopian tube (F). It contains both gelatinous and tubular nervous fibres.

38.38.38. A branch of the sympathetic, which proceeds from the inferior aortic plexus (26, &c.), and is distributed to the middle part of the uterus (D), also sending a branch (39) to the ovary (E). The branch passes down by the side of the lateral hypogastric plexus (29.29), but without being at all connected with it in this subject, and then enters the broad ligament passing up to the middle part of the uterus. It is formed of gelatinous and tubular fibres.

39. A branch which is sent to the ovary. Whether any branches come down from the renal plexus, in company with the spermatic artery, or not, I am unable to say, as the preparation was slightly injured in this part; but I am inclined to think that there were branches supplied to the ovary as seen in Plate XV.

40.40.40. Branches which pass from the lower border of the lateral hypogastric plexus to join the pelvic plexus.

41. The lumbo-sacral nerve.

42. Part of the ganglion on the sensitive root of this nerve.

43. The first sacral nerve.

44. The ganglion on this nerve.

45. The second sacral nerve.

46. The ganglion on this nerve.

47. The third sacral nerve.

48. The ganglion on this nerve.

49.49.49. The ends of funiculi which form the fourth sacral nerve.

50.50.50. Portions of the sacral plexus.

51. A branch of the fourth sacral nerve (49.49) distributed to the levator ani (S).

52. Branches from the third sacral nerve (47), which are distributed to the skin of the perinæum and labia majora (N).

53. Some of the same branches, which, being divided, are turned aside.

54.54.54. Branches from the third sacral nerve (47) distributed to the sphincter ani (R) and skin near the anus (P).

55.55. Branches from the fourth sacral nerve (49.49, &c.) distributed to the muscular fibres and skin, at the lower part of the vagina.

56.56. Large branches from the third sacral nerve (47) distributed to the clitoris (T).

57.57. The continuations of the preceding branch (56.56). In consequence of this branch lying across the preparation it became necessary to divide it, and to turn the ends to each side.

58.58. Branches of the sacral plexus which lie loose in the preparation.

59. A branch from the second sacral nerve (45) which joins the pelvic plexus (61.61, &c.).

60.60.60. Branches from the third sacral nerve (47) and from the fourth sacral nerve (49.49), which join the pelvic plexus (61.61, &c.). The branches from the third sacral nerve join the anterior part of the plexus, and are distributed to the bladder and tissues of the anterior part of the vagina, and those from the fourth sacral nerve join the posterior part of the plexus, and are distributed to the erectile tissue and tissues at the posterior part of the vagina, and also to the rectum.

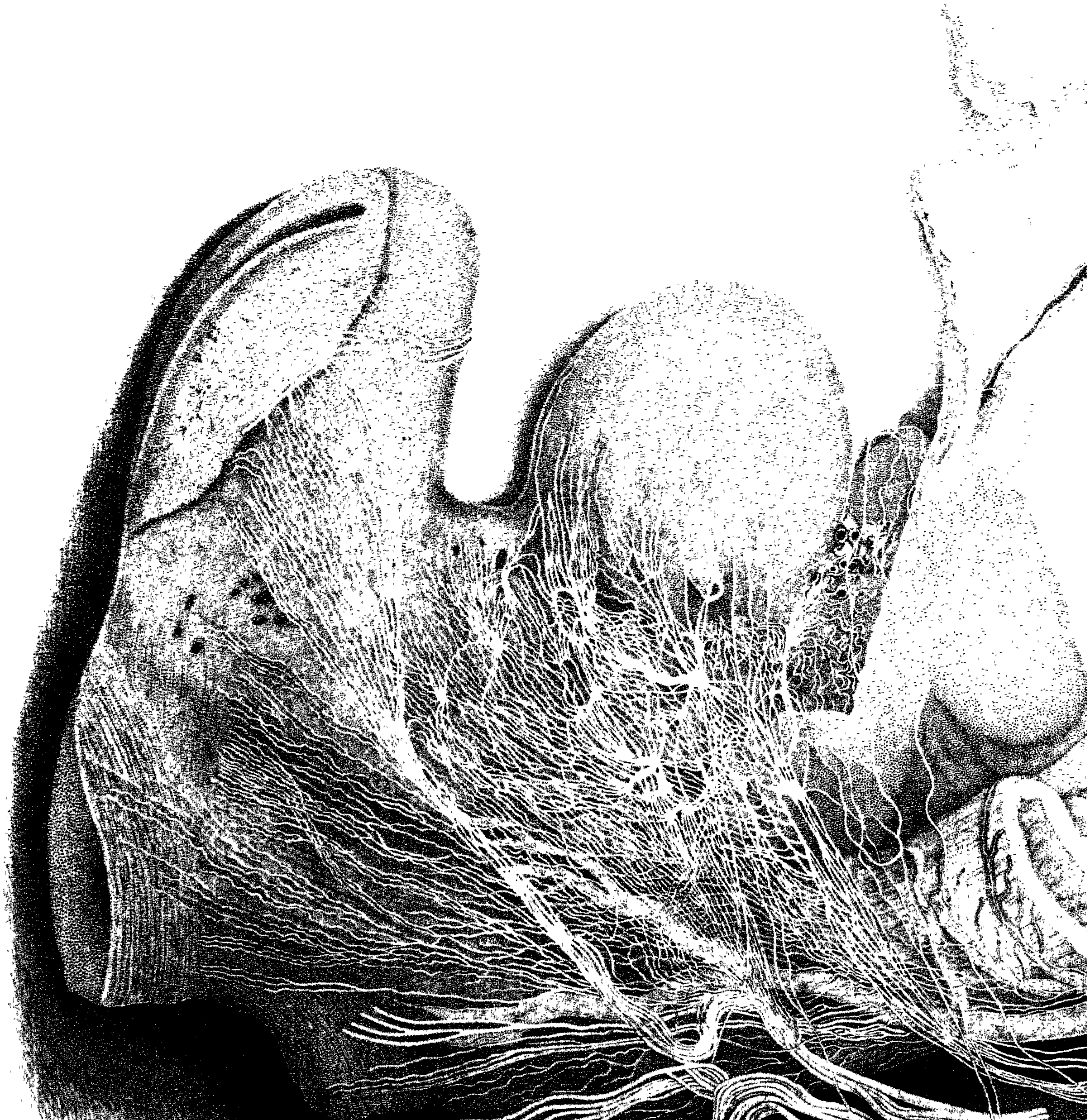
61.61.61.61.61.61. Small ganglia in the pelvic plexus. They are situated at the point of union between the branches from the lateral hypogastric plexus (29.29) and the branches from the sacral nerves (60.60.60). The lower part of the lateral hypogastric plexus forms a continuous plexus with the pelvic plexus, and the only circumstance which marks the division between the two is the existence of these ganglia, and the junction of the branches from the sacral nerves. It appears, however, from the marked difference which exists in their constitution, necessary to make this distinction between the two plexuses. For whilst the lateral hypogastric plexus (29.29) is a continuation of branches from the lower part of the superior aortic plexus (21.21, &c.), the pelvic plexus (61.61, &c.) is a point where a new arrangement of the gelatinous and tubular nervous fibres occurs, previous to the branches being distributed to the bladder, vagina and rectum. In this respect the pelvic plexus is analogous to the semilunar ganglion (3.3, &c.) and to the lower part of the superior aortic plexus (21.21, &c.), from which it differs in the amount of nerves sent from it, and the large amount of tubular fibres which these nerves contain. This analogy is further shown by the branches from the sacral nerves (60.60, &c.) being analogous to the abdominal splanchnic nerves (19.19 and 14.14), and to the thoracic splanchnic nerves (1.1. and 2.2), as being the medium by which the tubular fibres are distributed to the viscera. The sacral branches however differ from the splanchnic nerves in not being associated with any gelatinous fibres. These branches pass over the sacral ganglia of the sympathetic without having any connexion with them. In the branches of the sympathetic proceeding from the semilunar ganglion (6.6, &c.) and from the superior aortic plexus (22.22, &c.), and distributed to the abdominal viscera, the amount of the gelatinous fibre greatly exceeds that of the tubular; but in the branches from the pelvic plexus (61.61, &c.), distributed to the bladder and vagina, the amount of tubular fibre exceeds that of the gelatinous; and in the branches sent to the lower part of the rectum (68.68), the amount of tubular and gelatinous fibre is nearly equal. The gelatinous fibres found in the pelvic plexus are derived from the lateral hypogastric plexus, augmented by the gelatinous fibres which arise from the small ganglia (61.61, &c.). The tubular fibres are derived from the sacral nerves, though some tubular fibres from the lumbar nerves enter the plexus with the gelatinous fibres from the lateral hypogastric plexus.

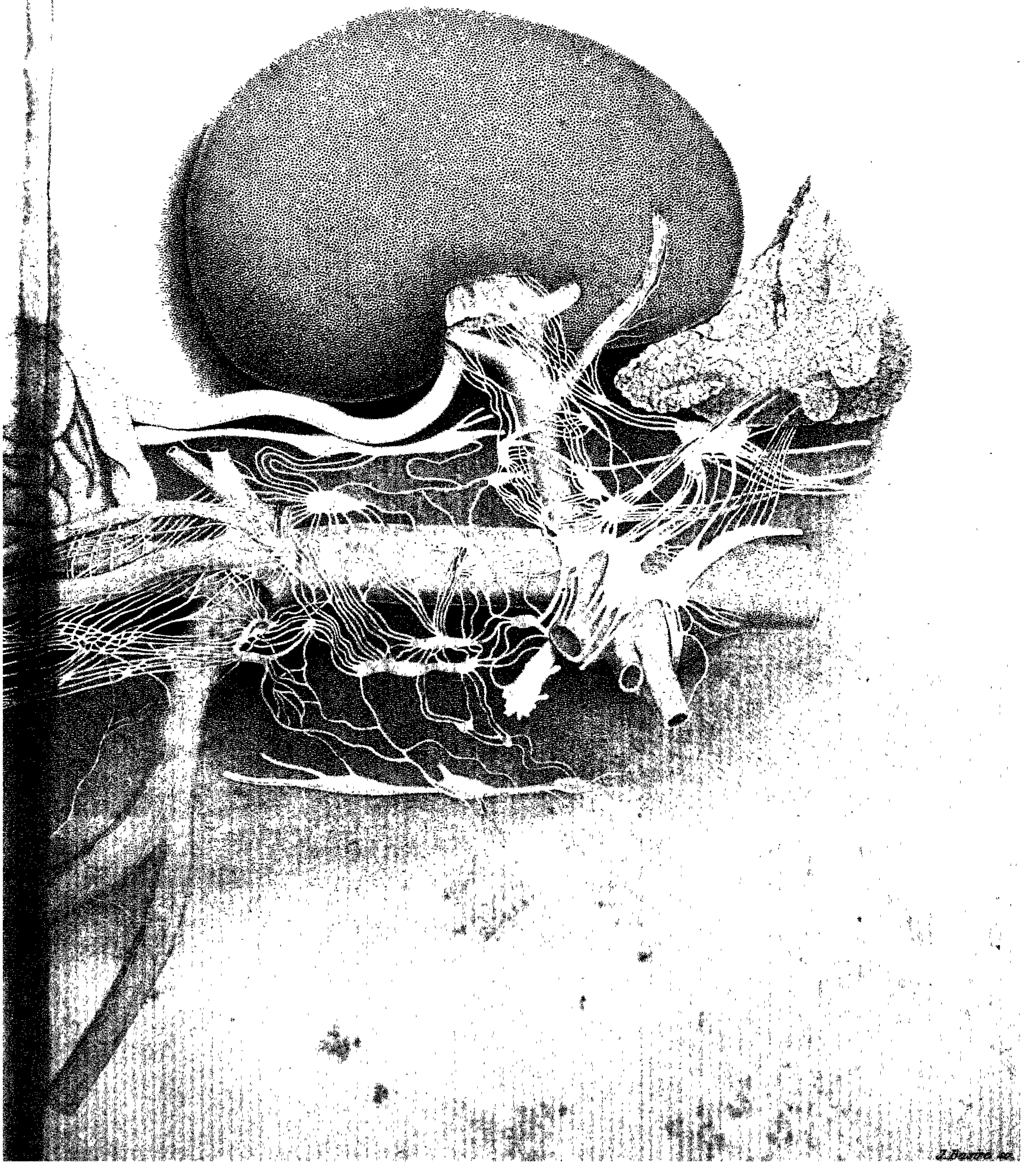
62.62.62.62.62. Small secondary ganglia which are formed in the pelvic plexus, and which assume various and curious forms.

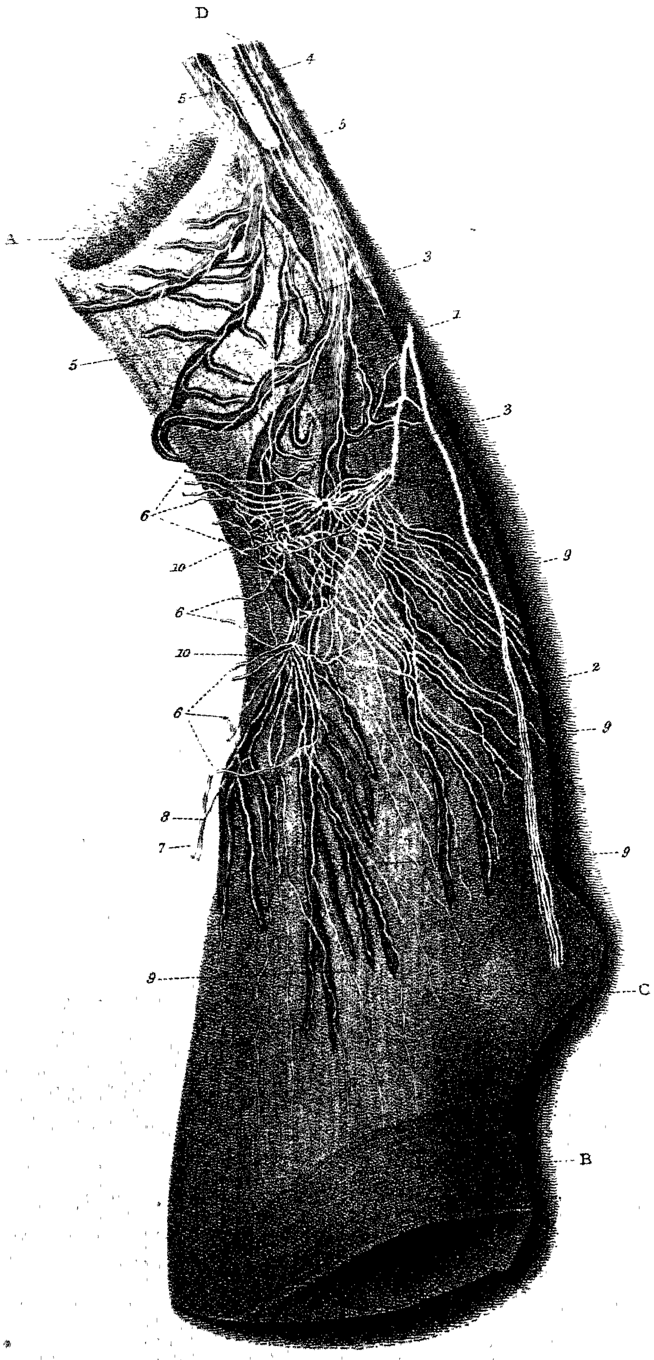
63.63.63.63. Branches from the anterior part of the pelvic plexus, which are distributed to the bladder. They contain a large amount of tubular nervous fibre.

64. Small ganglion on the vesical nerves.

65.65. Branches which come from the fourth sacral nerve, and joining with branches from the lower part of the pelvic plexus, are distributed to the erectile tissue (L).



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These sacral branches pass down by the side of the pelvic plexus, but have no communication with it.

66.66.66.66. Small ganglia formed on the nerves before they enter the erectile tissue.

67.67.67.67. Branches which enter the erectile tissue at the lower and anterior part of the vagina (L).

68.68.68. Branches which come from the posterior part of the pelvic plexus (61.61, &c.), and are distributed to the rectum.

PLATE XII.*.

A finished engraving of the preceding plate.

PLATE XIII.

Showing the posterior part of the pelvic plexus, which lies upon the rectum. This portion of the plexus is concealed in Plate XII. by the sacral nerves (47 and 49.49), and by the branches of the sacral nerves (59 and 60.60) lying upon it.

A. The upper part of the rectum.

B. The sphincter ani.

C. Fibres of the levator ani.

D. The two trunks of the superior hæmorrhoidal artery, as in Plate XII. The artery divides into branches which are distributed over the surface of the rectum.

1. A portion of the fourth sacral nerve.

2. A branch from the fourth sacral nerve sent to the levator ani.

3.3. Branches from the fourth sacral nerve which enter the posterior part of the pelvic plexus.

4. Three branches which come from the lower part of the superior aortic plexus (21.21, Plate XII.), and accompanying the superior hæmorrhoidal artery, end in the posterior part of the pelvic plexus.

5.5. Branches from the superior aortic plexus, which accompany the superior divisions of the hæmorrhoidal artery, before the formation of the pelvic plexus.

6.6.6. The divided ends of branches which enter into the formation of the pelvic plexus.

7. A branch distributed to the vaginal erectile tissue.

8. Small ganglion on this branch.

9.9.9.9. Branches from the pelvic plexus, which are distributed to the rectum. These branches follow the course of the arteries for some way, but leave the vessels in their ultimate distribution to the gut. They consist of gelatinous and tubular fibres in nearly equal proportions.

10.10. Small ganglia on the hæmorrhoidal nerves.

PLATE XIV.

A. The gravid uterus at the ninth month of pregnancy.

B. The right Fallopian tube turned aside.

C. The right ovary.

D. The right kidney, which has been cut at the lower part to show the structures beneath.

E. The right ureter.

F. The bladder.

G. The vagina.

H. The rectum.

I. A portion of the abdominal aorta.

K.K. Two renal arteries.

L. The renal vein.

M. The spermatic artery.

N. The continuation of the spermatic artery to the fundus of the uterus.

O. The division of the spermatic artery which supplies the ovary.

P. The superior hæmorrhoidal artery covered with fat. The nerves which accompany it are not dissected.

R.R. Portions of the superficial layer of muscular fibres which have been dissected out by Dr. Robert Lee, and described by him as nervous ganglia and plexuses. These muscular fibres adhere to the under surface of the peritoneum.

S. The edge of the divided peritoneum.

1.1. Portions of the semilunar ganglion.

2.2. Portions of the renal plexus.

3. The aortic plexuses.

4. The lateral hypogastric plexus.

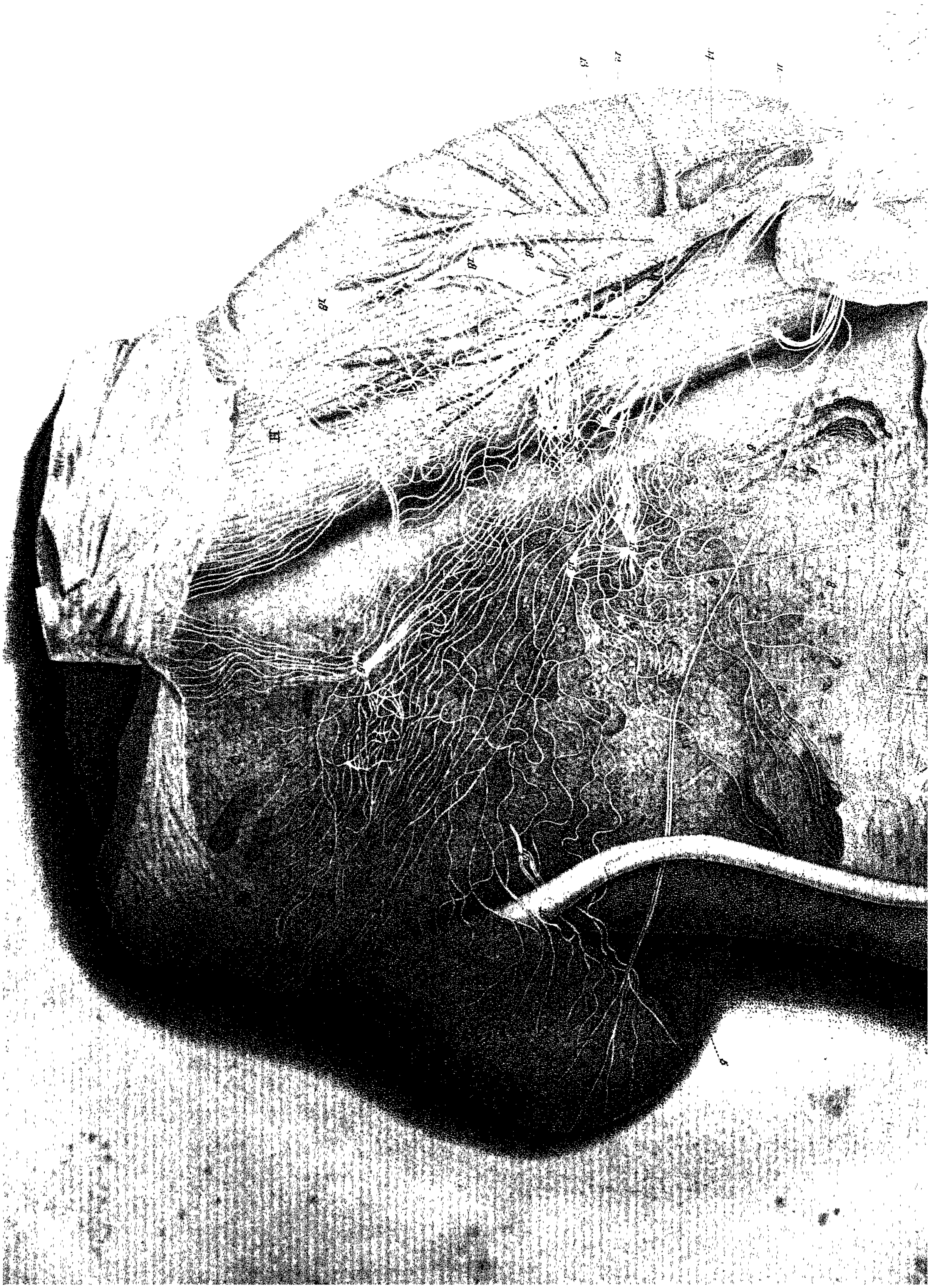
5. A continuation from the lateral hypogastric plexus, which is distributed to the superior part of the bladder.

6.6.6.6. Continuations from the lateral hypogastric plexus distributed to the lower half of the uterus.

7. A nervous branch which supplies the middle part of the uterus. It is inclosed in a tendinous canal, which extends to the bifurcation of the branch, and is apparently analogous to the branch described at 38. Plate XII. The difference which may at first appear to exist between these two branches passes away, when we remember that the lateral hypogastric and inferior aortic plexuses are both emanations from the superior aortic plexus.

8. A portion of the preceding branch, which has been divided in the dissection. It lies loose in the preparation.

9. A branch which accompanies the spermatic artery, but which was divided in removing the preparation from the body.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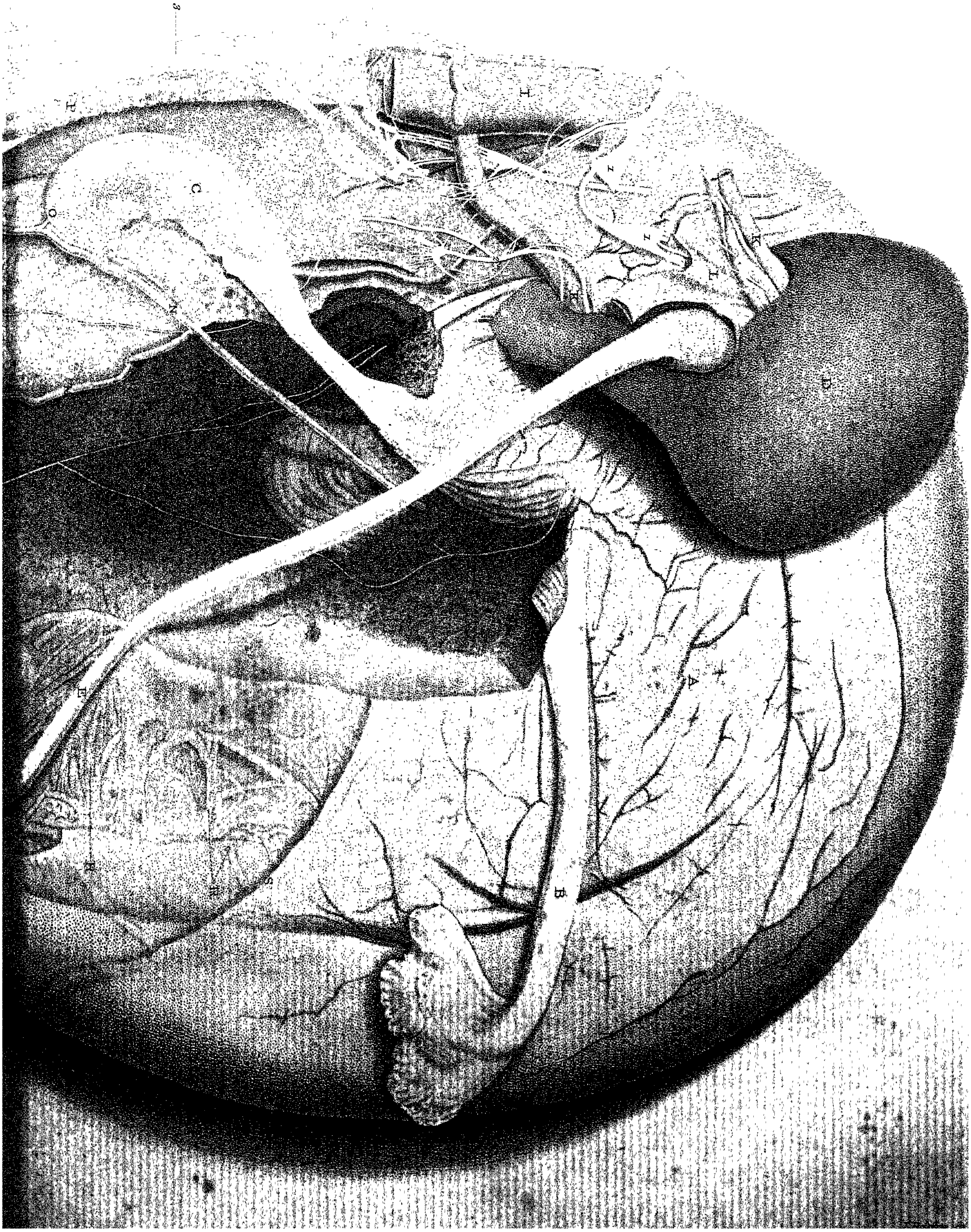
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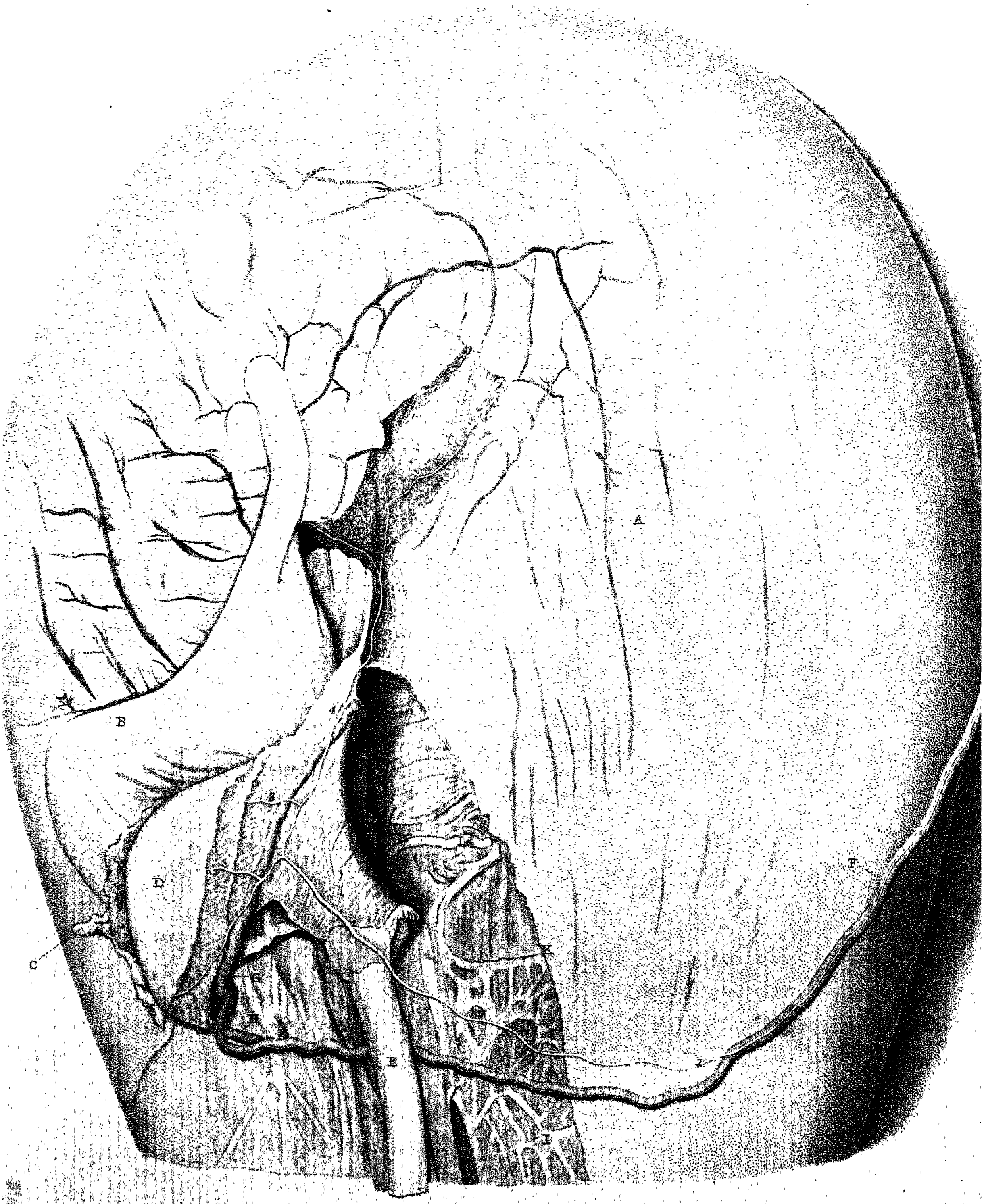
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10. Part of the sacral plexus.

11. Branches which enter the middle and anterior part of the pelvic plexus.

12. A branch which joins the posterior part of the pelvic plexus.

13. A branch from the sacral nerves distributed to the muscular tissues at the lower part of the vagina.

14. Branches which come down with the superior hæmorrhoidal artery and join the posterior part of the pelvic plexus.

15.15.15.15.15. Small ganglia in the pelvic plexus. Several smaller ganglia also exist in this plexus.

16.16.16. Nerves distributed to the bladder from the pelvic plexus.

17.17.17. Branches sent to the erectile tissue at the lower and anterior part of the vagina.

18.18.18. Branches from the posterior part of the pelvic plexus distributed to the rectum.

The formation and composition of the nerves in this dissection are, in all cases, exactly similar to that described in the previous dissection, Plate XII. Some of the branches, however, have been broken in consequence of my beginning the dissection with opinions very different from what I afterwards found to be correct.

PLATE XV.

Showing the distribution of the Nerve to the ovary and fundus of the uterus on the opposite surface of the same gravid uterus figured in Plate XIV.

A. The fundus of the gravid uterus at the ninth month of pregnancy.

B. The left Fallopian tube.

C. The fimbriated extremity of the Fallopian tube.

D. The left ovary.

E. A large vein.

F. The left spermatic artery.

G. The continuation of the spermatic artery to the fundus of the uterus.

H. The branch of the artery distributed to the ovary.

I.I. Another portion of the superficial layer of muscular fibres, which has been described as nervous ganglia and plexuses by Dr. Robert Lee.

K. The edge of the divided peritoneum.

1. A branch of nerve which proceeds from the renal plexus in company with the spermatic artery, and is distributed to the ovary and fundus uteri.

2. A fusiform enlargement formed on the nerve previous to its distribution.

3.3. Branches sent to the ovary.

4. A branch sent to the fundus of the uterus.

PHILOSOPHICAL
TRANSACTIONS
OF THE
ROYAL SOCIETY
OF
LONDON.

FOR THE YEAR MDCCCXLVI.

PART III.

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ERRATUM.

Page 259. Heading of Table VII. line 3, *for* from 261° to 268° 30′ *read* from 231° to 268° 30′.

PHILOSOPHICAL TRANSACTIONS.

XVII. *Contributions to Terrestrial Magnetism.—No. VII.*

By Lieut.-Colonel EDWARD SABINE, *R.A., For. Sec. R.S.*

Received April 30,—Read May 14, 1846.

Containing a Magnetic Survey of a considerable portion of the North American Continent.

FROM the moment that the fact was known, that the locality of the maximum of the magnetic Force in a hemisphere is not coincident, as was previously supposed, with the locality where the dip of the needle is 90°, researches in terrestrial magnetism assumed an interest and importance greatly exceeding that which they before possessed; for it was obvious that the hypothesis which then generally prevailed regarding the distribution of the magnetic Force at the surface of the globe, and which had been based on a too-limited induction, was erroneous, and that even the broad outline of the general view of terrestrial magnetism had to be recast.

The observations on which this discovery rested, (being those which I had had an opportunity of making in 1818, 1819 and 1820 within the Arctic Circle, and at New York in 1822,) were published in 1825[*]; they constituted, I may be permitted to say, an important feature in the views, which led the British Association in the year 1835 to request that a report should be prepared, in which the state of our knowledge in respect to the variations of the magnetic Force at different parts of the earth's surface should be reviewed, and, as is customary in the reports presented to that very useful institution, that those measures should be pointed out which appeared most desirable for the advancement of this branch of science. In the maps attached to the report[†], the isodynamic lines on the surface of the globe were drawn simply in conformity with observations, and unmixed with hypothesis of any sort. The observations collected for that purpose were not those of any particular individual or of any single nation, but embodied the results obtained by all persons who up to that period had taken part in such researches, subjected to such amount of discussion only as conveyed a knowledge of the modes of observation severally employed, and reduced the whole to a common unit. The observations thus combined gave for the highest isodynamic lines of the northern hemisphere, closed and irregularly elliptical curves, extending across the North American Continent nearly in a north-west and south-east direction, and having their central point, or the point of maximum of Force, approximately in 52° north latitude, and 270° east longitude*.

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[*] Pendulum and other Experiments, pp. 460–499.

[†] Reports of the British Association for 1837.

To confirm this previously unsuspected characteristic of the magnetic system of the globe,—to establish beyond a question so remarkable a fact in Physical Geography, —to fix within narrow limits the geographical situation of the point of maximum corresponding to a particular epoch,—to ascertain with the precision of modern instruments and methods the intensity of the magnetic Force at its point of maximum,— and to assign the form and geographical localities of the isodynamic curves adjacent to that point,—were objects which presented themselves amongst the most important desiderata for our present knowledge, and as likely to have a peculiar value at a future period in respect to the Ætiology of the science; when, like the earlier determinations in astronomy, these researches might serve to elucidate the laws of those secular changes, which, in our present ignorance of the causes of the earth's magnetism, seem even more mysterious than the apparently complex relations of contemporary phenomena.

The report referred to contained accordingly a suggestion of the expediency of measures being taken to procure a magnetic survey of that portion of the North American Continent, which is comprised within the isodynamic line of 1·8 in the arbitrary scale. This suggestion was treated as second in importance only to the recommendation which it was the primary object of that report to urge, and which has since been carried into execution; viz. a magnetic survey of the high latitudes of the southern hemisphere by a British naval expedition.

The extensive territory over which it would be necessary to travel, in order to execute the proposed survey in North America, forms a part of the British dominions on that Continent, and is annually traversed during the summer months by the boats of the Hudson's Bay Company conveying merchandize. A navigation conducted on lakes and rivers is better suited for the safe transport of small and delicate instruments, than where the travelling has to be performed exclusively on land. The good offices which the Hudson's Bay Company had contributed to the success of the geographical expeditions, undertaken by the British Government, for the purpose of tracing the American rivers and coasts of the polar sea, and their liberality in originating expeditions of the same nature, and in executing them at their own cost and by their own officers, justified the hope that assistance might be given by the Hudson's Bay Company, which should render an undertaking feasible, which undoubtedly would not have been so without their aid.

With this expectation, and having reason to believe that leave of absence from military duty might be obtained, I applied in 1839 to the respected Chairman of the Hudson's Bay Company, Sir JOHN PELLY, Bart., and received from him the assurance that a conveyance in the Company's boats from Montreal to York Factory, and back to Canada by a different route, would readily be granted me on my personal application; and I accordingly commenced the preparation of the instruments which I proposed to employ. The execution of this design was prevented by the appointment in that year of officers and detachments of the Royal Artillery to conduct the Colonial magnetic observatories: these were placed under my superintendence, and the publication of the observations made at them entrusted to me. The project of a North American magnetic survey, however, was not suffered to drop.

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* Vide Map 2 of the Report referred to.

Having ascertained from Sir JOHN PELLY that a conveyance in the Company's boats would be granted to an officer of the magnetic observatory at Toronto, on a representation from the President and Council of the Royal Society of the scientific interest attached to the undertaking, the late Lord VIVIAN, then Master-General of the Ordnance,—always desirous to encourage the officers who had the honour to serve under his command in rendering, in times of peace, such public though not strictly professional services as their public education qualified them to perform,—was pleased to annex the survey in question to the duties of the Toronto Observatory, and to add for that purpose an officer and a non-commissioned officer to the establishment of the observatory. This addition was proposed to Lord VIVIAN, with the concurrence and approval of the Deputy Adjutant-General of the Royal Artillery, Major-General Sir HEW DALRYMPLE ROSS, K.C.B.; and on Lord VIVIAN's recommendation, the Treasury granted extra pay to the officer and the non-commissioned officer, with 130*l.* for the purchase of instruments, and 50*l.* a year for three years for the contingencies of the survey.

On the proposal of Sir JOHN HERSCHEL, Bart., Chairman of the Committee of Physics of the Royal Society, the President and Council of that body addressed the Hudson's Bay Company in recommendation of the proposed undertaking, and received a favourable reply.

In the autumn of 1842, Lieut. (since Captain) LEFROY, of the Royal Artillery, who had been the director of the magnetic observatory at St. Helena, and was appointed to the Toronto Observatory with a special view to his employment on the survey, left England for America, accompanied by Bombardier (since Sergeant) HENRY of the same corps, to join the brigade of canoes of the Hudson's Bay Company, which would leave Montreal early in the following spring; the interval was employed in the preparation and trial of instruments, and in connecting, by an excursion in the United States, the observations about to be made in the British territories, with those which were in progress in different parts of the Union.

In January 1843 I waited on Sir GEORGE SIMPSON, by appointment, at the Hudson's Bay House, to arrange with him the route by which it would be convenient to the Hudson's Bay Company to convey Lieut. LEFROY, so as to enable him to fulfil the objects of his employment. It was proposed by Sir GEORGE SIMPSON that Lieut.

LEFROY should be conveyed, with his assistant and instruments, in one of the regular canoes of the brigade from Montreal to York Factory, and that from thence he should be provided with a light canoe to proceed, independently of others, to Moose Fort, near the head of Hudson's Bay, from whence he should return to Toronto overland as soon as the winter travelling should commence. By this route a circuit would be made completely round the supposed point of maximum of the Force, and within the isodynamic curve of 1·8. It was stated by Sir GEORGE SIMPSON, that the progress of the Brigade would admit of two hours in each day being taken for observation; that four hours would be given at each of the Company's posts, and twenty-four hours on the term-days of May and June; and that directions should be given accordingly to the conductor of the Brigade.

Lieut. LEFROY was provided with the following instruments:—

1. An Inclinometer of nine French inches diameter, by GAMBEY. This instrument is the property of Captain ROBERT FITZROY, R.N., and is the same which was previously lent by him for the survey of the British Islands, and by his permission is still employed for the public service. The needles belonging to it were the same which had been used in the British Survey, when they were proved to be free from index error at all inclinations, by the observations of Captain JOHNSON, R.N. and myself in the Regent's Park, reported in the account of that survey. Two additional needles were fitted to this instrument for the purpose of determining variations of the total force by Dr. LLOYD's method: they were made in 1839 by the late Mr. ROBINSON, and had been laid by in the hope that their magnetism would become steady.

2. A Fox's Inclinometer of seven inches diameter, with one reversing needle, and two needles for observing variations of the total force by Mr. Fox's method.

3. A portable unifilar magnetometer, for measurements of the absolute horizontal force, of the construction described in Lieut. RIDDELL's instructions for the use of portable magnetical instruments.

4. An azimuth compass of the construction proposed by the Committee for the improvement of ships' compasses, and now in use in Her Majesty's Navy; the bowl was reduced in height to render it more portable.

5. A portable declinometer.

6. A portable bifilar magnetometer; and

7. A portable induction inclinometer. These three instruments were designed for observations on term-days, and for the observations of diurnal variation and of disturbances in case of detention at any of the Company's posts.

Lieut. LEFROY was also furnished with a DOLLOND's repeating and reflecting circle and mercurial horizon, for determining geographical positions; with meteorological instruments, including an apparatus for measuring heights by the boiling-point of water; and with two pocket chronometers, which were kindly lent for the occasion by the Hydrographer of the Admiralty.

Lieut. LEFROY met Sir GEORGE SIMPSON at Montreal towards the end of April 1843, and embarked with Bombardier HENRY and the instruments on board one of the Company's canoes at La Chine, commencing his observations on the 24th of May, in the ascent of the Ottawa river. The weather being favourable observations were made daily, with not more than one or two exceptions, until the Brigade arrived at Fort William on the 29th of May. It was there proposed by Sir GEORGE SIMPSON, who had preceded the Brigade, that Lieut. LEFROY should be provided with a canoe to himself, and should follow the Brigade at his convenience, but be entirely independent of it. This arrangement was consequently adopted, and Lieut. LEFROY left Fort William furnished with a guide and a canoe at his exclusive disposal, to carry out the original design of proceeding to York Factory. At the Rat Portage, however, on the Lake of the Woods, on the 20th of June, an accident happened to GAMBEY's inclinometer, which was thrown down, the glass cover broken, and one of the LLOYD's needles injured; Lieut. LEFROY was induced by this accident to deviate from the direct course to York Factory, and to proceed to the Red River settlement, where the damage was repaired. Here he met Sir GEORGE SIMPSON, and being of opinion that he should best promote the objects of the Survey by passing a winter in the interior, instead of carrying out the plan at first proposed of returning to Canada from York Factory, he arranged with that gentleman that, after returning to Norway House from Hudson's Bay, he should proceed direct to Fort Chipewyan on Lake Athabasca, winter there, descend M'Kenzie's River in the spring to the Arctic Circle, visit the Company's posts on the Saskatchewan and Peace Rivers, and return to Toronto at the conclusion of the summer of 1844. By this arrangement a considerable extension was given to the survey, and an opportunity was afforded of making the observations of a fixed magnetic observatory during several months of winter at Athabasca, where the magnetic variations, both regular and irregular, are of great magnitude, and have particular interest: on the other hand, some expense was incurred which had not been originally contemplated or provided for. The plan thus formed was executed; and the present number of the Contributions contains the observations during this survey of two of the magnetic elements, viz. of the Inclination and of the Force; the Declination is reserved for a future occasion, because a considerable augmentation of materials is expected. The winter observations with the magnetometers will have an appropriate place in the publication which contains the observations at the Colonial Magnetic Observatories.

I am much gratified in being able to add to the interest and value of this number of the Contributions, by including observations not previously published, communicated to me by several gentlemen of the United States. In acknowledging the liberality and disinterested view for the advancement of science, with which the results of laborious and extensive researches have thus been unreservedly placed at my disposal, in anticipation of the publications in which they will respectively appear, I have great pleasure in calling attention to this example of the cordiality and good feeling, which happily subsist amongst the individuals of different nations, who have a common bond of union in the cultivation of magnetical science.

I am indebted to Major JAMES D. GRAHAM of the Corps of Topographical Engineers of the United States, (Commissioner for exploring the North-Eastern Boundary of the United States under the act of Congress of July 20th, 1840, Principal Astronomer and Head of the Scientific Corps on the part of the Government of the United States for the joint survey and demarcation of the Boundary under the Treaty of Washington,) for the results of observations of the Inclination made from 1841 to 1845 at thirty-eight stations, chiefly in the parts of the country in which the Boundary Commissioners have been engaged. These observations were made with an inclinometer by GAMBEY, with the exception of three stations, where an instrument of TROUGHTON and SIMMS was employed*; they appear to have been made with extreme care, and the results are remarkably accordant and satisfactory. Major GRAHAM's observations have a particular value, in placing beyond question the fact that the direction of the isoclinal lines in that part of the American Continent is to the northward of east, whilst in the whole range of country elsewhere comprehended in this survey, these lines have a direction more or less from the northward of west to the southward of east: the geographical position in which certain of the isoclinal lines attain their greatest southing is thus satisfactorily ascertained. Major GRAHAM states that the results now communicated are abstracted from a paper which has been presented to the American Philosophical Society of Philadelphia, and which will be hereafter published in the Transactions of that Society.

From Dr. LOCKE of Cincinnati I have received the result of a very extensive series of observations of the Inclination and Force, on which he has been engaged for eight years (1838 to 1845 inclusive), comprehending the determination of both elements at about 100 stations, distributed in longitude from the seaboard of the United States to the Mississippi River, and in latitude from 38° to 48°. It is in fact a magnetic survey of the Inclination and Force over the north-western and north-eastern States of the Union, conducted by an individual on his own unaided resources, and is one of the many notable instances of private research elicited by the impulse and systematic direction which have been given of late years to the study of terrestrial magnetism. The full account of these observations is designed to be published in the Transactions of the American Philosophical Society; but in the mean time the results have been spontaneously communicated to me by Dr. LOCKE (with whom I had not previously the pleasure of being acquainted), with full permission to make such use of them as I might deem advantageous to science. The Inclinations were observed with an inclinometer made by the late Mr. ROBINSON, and the variations of the magnetic Force by a HANSTEEN's apparatus, in which the needles vibrate in a partial vacuum, according to the plan devised by Dr. ALEXANDER DALLAS BACHE.

To Dr. A. D. BACHE, Director of the Coast Survey of the United States, and to JAMES RENWICK, Esq., late Commissioner for Surveying and Exploring the North-Eastern Boundary of the United States, I am indebted for observations of the Inclination and of the absolute horizontal Force, which have been made by direction of the Government of the United States at stations of the Coast Survey, and which will hereafter be published in the Government reports. In the mean time the results have been communicated to me by Dr. BACHE, with the permission of the Government.

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* These stations were the Military Academy, West Point, New York; near the monument for marking the source of the River St. Croix; and Park's Hill on the boundary of Maine and New Brunswick.

I have also availed myself of the Inclinations observed in different parts of the United States, by Professor LOOMIS and M. NICOLLET, published in the seventh and eighth volumes of the Transactions of the American Philosophical Society. The skill of these gentlemen as observers, and the scrupulous care with which their observations are recorded, are too well-known to require comment.

In conformity with the plan adopted in former numbers of these Contributions, I shall now proceed to discuss the general results of the observations embodied in this memoir under the separate heads of Magnetic Force and Inclination; referring where necessary to the documents in the sequel.

Magnetic Force.

The statical observations of the total Force furnish determinations at 120 stations, at 73 of which LLOYD's needles were employed, and Fox's needles at 109 stations. The observations of the horizontal force, with the magnets of the portable magnetometers, furnish determinations at 57 stations. The statical and horizontal methods together comprise 140 stations: the observations are given, and the results deduced in § 11. To these we have to add 10 determinations made at 10 stations near New York by Mr. RENWICK, with a portable unifilar; and the ratios of the horizontal force at 101 stations, chiefly in the United States, by Dr. LOCKE, with a HANSTEEN's apparatus in which the needles vibrated in a partial vacuum. The connection of Dr. LOCKE's observations with those of Lieut. LEFROY, has been established by means of eleven stations common to both series, enabling both to be expressed in a common unit. The general table, No. XLVIII., which concludes § 11, comprehends 288 determinations of the magnetic force at 234 stations. Of the determinations 32 are of the absolute horizontal force, in which the magnetic moments of the magnets employed were examined on the spot: 35 were obtained with the same magnets, and give also the absolute horizontal force, but the magnetic moments were computed for the stations from experiments of deflection at other stations: 101 are of the ratios of the horizontal force, observed with needles whose magnetism was proved to be constant by their having been frequently brought back and examined at a base station; and 120 are ratios of the total force obtained by the statical method, in which also the magnetism of the needles was proved by their having been brought back to a base station. The number of stations at which statical ratios only were obtained is 74; the number at which horizontal ratios only were observed is 85; the number of the stations of absolute horizontal determinations only (whether by vibrations and deflections, or by vibrations alone) is 29; and finally, there are 37 stations at which both absolute and relative determinations were made.

As all the stations of relative determination have the observatory at Toronto as a common base, it becomes an object to investigate with more than ordinary care the value of the total magnetic Force at that observatory, both in the arbitrary scale and in absolute measure.

In the present state of experimental methods and apparatus we must obtain the absolute Force from the observations of its horizontal component, combined with observations of the Inclination. At Toronto we have for this purpose the values of the horizontal component resulting from the regular monthly series, made in the observatory on the 16th, 17th and 18th of each month in the year 1845, with a suspended magnet of three inches, and a deflecting magnet of 3·67 inches, the same magnets being used throughout. The details of these observations will be printed in the volume of the proceedings at the Toronto Observatory for the year 1845; the results are as follows:—

January .	3·5377.	April . .	3·5351.	July	3·5413.	October . .	3·5373.
February .	3·5376.	May . .	3·5388.	August. . .	3·5383.	November.	3·5360.
March . .	3·5375.	June. .	3·5421.	September.	3·5373.	December.	3·5379.

The mean of the twelve months is 3·5380; and the mean of the Inclinations observed on the days in each month, nearest to those on which the Force was observed, is 75° 15′·5: hence we have for the total force in absolute measure, 13·904.

The magnets employed in the preceding determination were those of the Observatory unifilar. In September of the same year (1845), a very careful series of observations were made with the magnets Nos. 30, 31 and 17, of the unifilar magnetometer which had been employed on the survey; the particulars are given in the following Table:—

TABLE I.—Observations on the absolute Horizontal Force made at Toronto with the Survey bars, Nos. 30, 31 and 17, in September 1845, reduced to the mean reading of the Bifilar Magnetometer for the day of observation.

Date.	Bars.	Distances.	Bifilar.				Deflections.		Vibrations.		Corresponding bifilar.		Suspension.	Value of *m*.	Value of X.
			Mean of the day.		At the observation.										
			Sc. div.	Therm.	Sc. div.	Therm.	Angles.	Therm.	Times.	Therm.	Sc. div.	Therm.			
		feet.		°		°	° ′ ″	°	s.	°		°			
Sept. 19.	30	1·0257	568·9	64·0	564·2	65·0	11 26 26	61·5	4·8666	61·6	558·2	64·4	*s.*	·3806	3·5311
19.	30	1·0257	......	......	569·7	64·9	8 37 49	61·8	4·0136	62·7	565·2	65·9	...	·3805	3·5315
19.	30	1·2257	......	......	572·0	64·7	6 40 47	61·9	....	......	......	......	...	·3806	3·5311
19.	30	1·3257	......	......	571·7	65·2	5 16 35	61·5	....	......	......	......	...	·3806	3·5313
20.	31	1·0257	575·5	60·2	569·9	62·1	9 54 19	61·3	4·3292	60·0	558·3	61·9	...	·3305	3·5353
20.	31	1·1257	......	......	571·2	62·1	7 29 4	61·3	5·2409	62·0	575·9	62·4	*s.*	·3306	3·5347
20.	31	1·2257	......	......	569·6	62·1	5 47 35	61·5	....	......	......	......	...	·3305	3·5354
20.	31	1·3257	......	......	569·3	62·0	4 34 53	61·7	....	......	......	......	...	·3306	3·5340
22.	17	1·1517	589·2	56·3	592·6	57·2	13 26 57	55·8	4·4196	57·6	592·8	57·9	...	·6291	3·5390
22.	17	1·4517	......	......	591·6	57·1	6 39 38	56·2	4·4149	56·0	584·7	55·8	...	·6290	3·5396
24.	17	1·1517	573·1	57·4	586·8	57·0	13 26 2	57·5	4·4138	56·5	581·1	56·7	...	·6287	3·5362
24.	17	1·4517	......	......	587·0	57·0	6 39 11	57·5	....	......	......	......	...	·6279	3·5404
															3·5350

The 2nd observation of vibration of bar 17 entered on the 22nd was made on the 23rd, but is reduced to the mean bifilar reading of the 22nd. When *s.* is inserted in the column entitled "suspension," it implies that the magnet was suspended in a stirrup; otherwise the magnet was suspended without a stirrup. The value of π^2K for bar 30 is 21·580 without the stirrup, and 31·745 with the stirrup; for bar 31, 21·853 without the stirrup, and 32·004 with the stirrup.

The mean result of this series is 3·5350; and the Inclination from observations made on the same days 75° 15′·8: hence we have the total force 13·897.

Finally, we have another series made with Nos. 30 and 31 in April 1846, and on this occasion unusual care was bestowed on the observations both of the Force and of the Inclination, preparatory to a repetition with the same instruments at Woolwich, for the purpose of making the comparison between Woolwich and Toronto as *relatively* correct as possible. The particulars of these observations are contained in the following Tables:—

Table II.—Observations on the absolute Horizontal Force made at Toronto with the Survey bars Nos. 30 and 31, in April 1846, reduced to the mean reading of the Bifilar Magnetometer for the day of observation.

Date.	Bars.	Distances.	Bifilar.				Deflections.		Vibrations.		Corresponding bifilar.		Value of *m*.	Value of X.
			Mean of the day.		At the observation.									
			Sc. div.	Therm.	Sc. div.	Therm.	Angles.	Therm.	Times.	Therm.	Sc. div.	Therm.		
		feet.							s.					
April 6.	31	1·026	579·5	55°·0	572·6	56°·3	10° 27′·9	59°·2	4·2061	50°	581·0	54°·5	0·349	3·538
6.	31	1·126	…………	………	606·6	57·0	7 54·5	58·2	4·2062	50	615·6	57·1	0·349	3·535
7.	30	1·026	580·5	55·4	576·5	56·2	11 28·0	48·5	4·0084	50	573·2	54·5	0·380	3·530
7.	30	1·126	…………	………	573·8	56·5	8 39·4	48·8	4·0114	50	578·7	56·6	0·380	3·530
8.	31	1·026	592·4	51·7	581·6	52·2	10 28·8	48·7	5·0985	50	586·7	51·6	0·348	3·535
8.	31	1·126	…………	………	584·0	52·1	7 54·9	48·3	………	………	…………	…………	0·348	3·535
8.	31	1·226	…………	………	586·2	52·1	6 8·0	48·3	5·0995	50	592·3	52·7	0·348	3·533
9.	30	1·026	595·6	51·2	581·7	52·8	11 23·3	61·2	4·8685	50	588·2	51·2	0·379	3·532
9.	30	1·126	…………	………	583·2	52·7	8 36·0	62·0	………	………	…………	…………	0·379	3·531
9.	30	1·226	…………	………	582·5	52·6	6 39·4	62·5	4·8749	50	594·9	53·6	0·379	3·531
														3·533

Table III.—Observations of the Inclination made on the Pedestal of the Telescope used in the Observations of Vibration, and intended for comparison with a Base series of observations of the absolute Horizontal Force. April, 1846.

Date.	Observer.	Poles direct.					Poles reversed.					Mean Inclination.
		a.	*a′*.	*a″*.	*a‴*.	Mean.	*b*.	*b′*.	*b″*.	*b‴*.	Mean.	
April. 6 A.M.	L.	74° 55′·8	75° 42′·9	75° 29′·1	74° 43′·6	75° 12′·8	75° 4′·8	75° 31′·6	75° 33′·1	75° 2′·8	75° 18′·1	75° 15′·5
P.M.	H.	75 3·8	75 45·6	75 32·8	75 1·7	75 21·0	75 2·2	75 30·9	75 27·6	74 46·2	74 11·7	75 16·3
7 A.M.	H.	75 4·3	75 34·8	75 34·8	75 4·0	75 19·4	74 57·4	75 41·8	75 31·4	74 44·4	75 13·7	75 16·5
P.M.	H.	75 4·3	75 31·2	75 24·9	74 48·1	75 12·1	75 1·4	75 45·3	75 33·2	75 1·4	75 20·3	75 16·2
8 A.M.	Y.	74 54·9	75 41·1	75 24·0	74 38·2	75 9·5	75 3·5	75 27·7	75 39·7	74 56·3	75 16·8	75 13·1
P.M.	H.	75 3·7	75 43·1	75 33·9	75 0·8	75 20·4	75 1·1	75 29·1	75 31·3	74 44·5	75 11·5	75 16·0
9 A.M.	L.	75 6·3	75 31 6	75 30·2	75 1·0	75 19·3	75 2·4	75 37·2	75 39·3	75 2·6	75 20·3	75 18·8
P.M.	L.	74 56·1	75 27·5	75 33·2	74 45·4	75 10·5	74 58·8	75 42·9	75 36·7	75 0·6	75 19·2	75 15·0
11 A.M.	W.	74 56·2	75 38·4	75 21·2	74 46·0	75 10·4	75 3·0	75 30·8	75 31·0	75 2·2	75 16·7	75 13·6
13 A.M.	H.	75 3·2	75 39·7	75 34·1	75 3·3	75 20·1	75 0·5	75 29·3	75 28·4	75 45·6	75 10·9	75 15·5
Mean Inclination, corresponding to the series of absolute horizontal Force………												75 15·65

The instrument employed was **Gambey**'s circle. Needle 1 was used for all the A.M. observations, and Needle 2 for all the P.M. observations, with the exception of the A.M. observation on the 13th, for which 2 was employed. The observers were, L. Lieut. **Lefroy**; Y. Lieut. **Younghusband**; H. Sergeant **Henry**; W. Sergeant **Walker**.

The mean of this series of the Force is 3·5330, and of the Inclination 75° 15′·65; hence we have the total Force 13·887.

The three determinations are as follows:—

By the observatory magnets in the twelve months of 1845 . . .	13·904
By the three survey magnets in September 1845	13·897
By two of the three survey magnets in April 1846	13·887

Whence we have the total Force in absolute measure at Toronto =13·896.

For the value of the total Force in the arbitrary scale, we have,—

1. A determination of the absolute Horizontal Force at Woolwich in June 1846, made by Captain Lefroy with the survey magnets Nos. 30 and 31, as shown in the following Table:—

Table IV.—Observations of the absolute Horizontal Force, made at Woolwich with the Survey bars Nos. 30 and 31. The corresponding readings of the Bifilar at Greenwich, kindly communicated by Mr. Airy, are inserted for reference. The times of vibration are entered as reduced to the common temperature of 80°, and corrected for torsion and rate: the angles of deflection are entered as observed.

Date.	Bar.	Distance.	Deflection.			Vibration.			Values of m.	Values of X.	
			Angles.	Therm.	Bifilar at Greenwich.	Times.	Therm.	Bifilar at Greenwich.			
1846.		feet.	° ′	°		s	°				
June 8.	30	1·026	10 43·5	75·7	......	4·7621	80	0·01897	0·375	3·725	3·7284
8.	30	1·126	8 6·0	76·0	0·01938	......	80	....	0·375	3·725	
8.	30	1·226	6 15·8	79·3	......	3·9287	80	0·01973	0·375	3·726	
11.	31	1·026	9 47·9	85·2	......	4·9944	80	0·01872	0·344	3·730	
11.	31	1·126	7 23·7	85·8	0·01977	......	80	....	0·344	3·732	
11.	31	1·226	5 43·0	84·5	......	4·1204	80	0·02112	0·344	3·735	
12.	31	1·026	9 45·6	89·0	0·01888	4·1240	80	0·01826	0·344	3·727	
12.	31	1·126	7 22·4	91·0	......	4·9975	80	0·02221	0·344	3·727	

The mean is 3·7284; and the mean of eight observations of the Inclination, made also between the 8th and 12th of June, with the same needles of Gambey's Inclinometer which had been employed to give the Inclination at Toronto, was 68° 57′·9; hence we have the total force in absolute measure at Woolwich =10·388.

We have therefore the total magnetic Force at Toronto to that at Woolwich as 13·896 to 10·388; or as 1·338 : 1: and taking 1·372 as the Force at Woolwich expressed in the arbitrary scale, we have the corresponding value at Toronto 1·835.

2°. A statical determination of the ratio of the Force at Toronto and Woolwich by Mr. Fox's apparatus, conveyed by Lieut. Lefroy in 1842 from Woolwich to Toronto; the particulars will be found under their proper dates in the general detail of the observations in § 11; the result was 1·340 at Toronto to unity at Woolwich; or 1·838 to 1·372.

3°. A second statical determination with the same apparatus, which Captain

Lefroy, having occasion to return to England in the spring of 1846, brought with him from Toronto to Woolwich for that purpose. The particulars are contained in the subjoined Table; the ratio resulting from them is identical with that obtained by the absolute method, viz. 1·835 to 1·372.

Table V.—Observations with Fox's Circle to determine the relative Intensity of the Magnetic Force between Toronto and Woolwich. Needle C. $q = ·00017$.

Station.	1846.	Angles of deflection. 1·5 gr.	2·0 grs.	2·5 grs.	3·0 grs.	Thermometer.	Intensity. Woolwich = 1·372.
Toronto ..	March 28.	19° 59′·2	27° 44′·7	35° 19′·7	44° 18′·5	42·6	1·835
	March 31.	20 02·8	27 37·7	35 11·0	44 13·5	57·3	
	April 2.	19 59·5	27 39·6	35 13·5	44 18·0	69·0	
Woolwich..	May 26.	27 03·2	38 34·6	50 41·7	69 42·5	68·4	1·372
	May 28.	27 14·5	38 33·8	50 53·2	69 30·3		

We have therefore three determinations of the total Force at Toronto expressed in the arbitrary scale, which are as follows:—

By the statical method in 1842	1·838
By the absolute method in 1845–46	1·835
By the statical method in 1846	1·835

I have therefore concluded on taking 1·836 as the value in the arbitrary scale of the total Force at Toronto; and as all the relative determinations discussed in this memoir were either originally made in reference to Toronto as a base station, or have become connected with it by subsequent comparison, they form one series, and the values expressed in this scale, in the general table, No. XLVIII., are all dependent on 1·836 as the Force at Toronto; and will all require to be increased or diminished should future investigations show that 1·836 has been incorrectly adopted.

Having then the values of the total Force at Toronto, 1·836 in the arbitrary scale, and 13·896 in absolute measure, arbitrary values are convertible into absolute by the factor $\frac{13·896}{1·836}$, and absolute into arbitrary by $\frac{1·836}{13·896}$. The absolute values of the total Force in the general table, No. XLVIII., have been thus computed in all cases when the original determination was a ratio, either total or horizontal; when the original determination was of the absolute horizontal Force, the absolute total Force computed therefrom is the product of the horizontal component and the secant of the observed Inclination.

The simplest form, in which an approximate representation of the isodynamic ovals round the point of maximum, and within a limited distance of it, may be computed from observations distributed in the space included by those lines, appears to be that of concentric and similar ellipses. The representation will not be strictly just, because the curves which include the two points of maximum in a hemisphere are of the nature of lemniscates, and not of true ellipses, and the curves of higher intensity inclosed within them partake of the same form. I have taken for a calculation of this nature all the observations by the statical methods of LLOYD and FOX in which the resulting value of the Force equals or exceeds 1·838; with the exception of two stations, viz. the Little Rock Portage and Pierre au Calumet, where a comparison of the values, both of the Inclination and Force, with those at adjacent stations, shows that a great disturbing influence prevailed: and I have included the three stations at the foot of the Rocky Mountains, viz. Forts Vermilion, Dunvegan and Edmonton, where the intensity is less than 1·838, but the position important; as well as Toronto, where the value of the force is just beyond the limit (being 1·836), but has the advantage of having been remarkably well determined. The number of stations in this combination is seventy-eight, and double weight has been given to four, viz. Norway House, Cumberland House, Shamatawa and York Factory, on account of the repetition of the observations. These stations furnish therefore eighty-two equations of condition of the form described in the following Note, for which I am indebted to ARCHIBALD SMITH, Esq., of Lincoln's-Inn, Fellow of Trinity College, Cambridge.

"*Note on the calculation of the Isodynamic Curves and the Focus of greatest intensity in North America.*

"These isodynamic curves consist of a series of ovals surrounding the point of greatest intensity.

"The method of combining the observations at different stations which was used in the Magnetic Survey of Great Britain*, and which proceeded on the assumption that the isodynamic lines were nearly straight, cannot therefore be applied. The most simple assumption which will give an approximate result, and admit of all the observations within a given limited space being combined in the calculation, appears to be the following:—

"Let a place near the centre of the region which is to be included in the calculations, be taken as the central station and origin of coordinates. Let y_1 and y_2, &c. be the differences of the latitudes of the several stations (which may be called s_1, s_2, &c.), and that of the central station:

"Let x_1, x_2, &c. be the differences, multiplied respectively by the cosines of the latitudes of s_1, s_2, &c., of the longitudes of s_1, s_2, &c., and that of the central station.

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* See Reports of the British Association for 1838.

"The position of a station of observation is thus determined by a distance in geographical miles measured along the meridian which passes through the central station, and a distance in geographical miles measured along that parallel of latitude which passes through the station of observation.

"Let z be the magnetic element whose value is to be determined, which in this case is the total intensity, and let z_1, z_2, &c. represent the values observed at s_1, s_2, &c.

"Assume that z may be expressed by the formula

$$z=ax^2+bxy+cy^2+dx+ey+f.$$

"This amounts to assuming that the isodynamic curves may be represented by a series of similar and similarly situated concentric ellipses, on a plane projection of the sphere, in which parallels of latitude are represented by equidistant horizontal straight lines, the meridian passing through the central station by a vertical straight line, and the other meridians by curved lines which all intersect in the projection of the poles, and each of which intersects the projection of the equator at right angles at a distance from the central meridian proportional to the difference of its longitude and that of the central meridian, (and equal to the projection of a corresponding number of degrees of latitude,) and intersects the other parallels of latitude at distances from the central meridian, which are to the last-mentioned distance as the cosines of the latitude of the respective parallels of latitude are to unity.

"Each station gives an equation of the form

$$z_1=ax_1^2+bx_1y_1+cy_1^2+dx_1+ey_1+f$$
$$z_2=ax_2^2+bx_2y_2+cy_2^2+dx_2+ey_2+f$$
$$\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot$$
$$z_n=ax_n^2+bx_ny_n+cy_n^2+dx_n+ey_n+f.$$

"These equations being properly *weighted* are then combined by the method of least squares, and the values of the constants a, b, c, d, e and f are to be determined by elimination. One test of the applicability of this method is, that the resulting curves should be ellipses and not hyperbolas; a and c must therefore have the same signs, and $4ac$ must be greater than b^2.

"Having determined the constants a, b, &c., the coordinates $\bar{x}$, $\bar{y}$ of the common centre of the ellipses, which is also the place of the greatest intensity, are given by the equations

$$2a\bar{x}+b\bar{y}+d=0,$$
$$b\bar{x}+2c\bar{y}+e=0,$$

which give $\bar{x}=\frac{be-2cd}{4ac-b^2}$. . . . (1.) $\bar{y}=\frac{bd-2ae}{4ac-b^2}$. . . . . (2.)

The maximum value of the intensity is

$$\bar{z}=f+\frac{bde-cd^2-ae^2}{4ac-b^2}. \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (3.)$$

"If θ be the angle which either axis of the ellipses makes with the parallels of latitude, we have

$$\tan 2\theta = \frac{b}{a-c} \quad \ldots \ldots \ldots \ldots \quad (4.)$$

"This expression is ambiguous, giving two directions at right angles to each other, and does not determine which of these directions is that of the major axis. This will generally be apparent from the observations themselves; and it may be determined by this consideration, that if the numerical value of a be greater than that of c, the inclination of the major axis to the parallel of latitude is greater than 45°; if less, less.

"The values of the semi-axes of the isodynamic ellipse for which the intensity has the value z, are given by the two values of the expression

$$\text{semi-axis} = \sqrt{\frac{2(z-\bar{z})}{a+c \pm \sqrt{(a-c)^2+b^2}}} \quad \ldots \ldots \ldots \quad (5.)$$

"The proportions of the semi-axes are

$$a+c \pm \sqrt{(a-c)^2+b^2} : 4ac-b^2 \quad \ldots \ldots \ldots \ldots \quad (6.)$$

"The simplest method of drawing the isodynamic ellipses will be to lay down the parallels of latitude and meridians in the manner above described; the isodynamic curves are true ellipses on that projection and may be easily constructed, and the points at which they intersect the meridians and parallels of latitude may then be laid down on any other map." A. S.

Lincoln's Inn.

I have taken the intersection of the latitude of 53° with the meridian of 260° as the origin of coordinates; the values of x_1, x_2, &c., y_1, y_2, &c., were taken in units each of ten geographical miles; and, for convenience in calculation, the excess above 1·798 has been taken at the value of z, the observed force at each station, and the decimals regarded as integers; the eighty-two equations thus furnished of the form described in Mr. SMITH's Note have been combined by the method of least squares, to obtain the most probable values of the constants a, b, c, d, e and f, the calculations having been performed by Sergeant McGRATH and Corporal HENDLEY of the Royal Artillery, independently of each other, and agreeing; the six final equations were:—

$$\begin{array}{rrrrrrr}
+5081 = & +134394a & -69949b & +48449c & +1632d & -660e & +82f \\
-37298 = & -3779899a & +2198523b & -1142033c & -69949d & +48449e & -660f \\
+98527 = & +7136612a & -3779899b & +2198523c & +134394d & -69949e & +1632f \\
+2603880 = & +177659938a & -96701976b & +57677688c & +2198523d & -1142033e & +48449f \\
-3570819 = & -323660394a & +177659938b & -96701976c & -3779899d & +2198523e & -69949f \\
+6822989 = & +622718413a & -323660394b & +177659938c & +7136612d & -3779899e & +134394f,
\end{array}$$

From these equations the values of the constants were obtained by elimination as follows:—

$a=-{\cdot}01138$ $d=+\ 0{\cdot}5633$
$b=-{\cdot}02522$ $e=+\ 0{\cdot}4485$
$c=-{\cdot}0356$ $f=+72{\cdot}54$.

With these constants we obtain

$\bar{z}=79{\cdot}9$; and the Force at the point of maximum $=(1{\cdot}798+{\cdot}0799=)1{\cdot}878$:

$\bar{x}=+29{\cdot}38$; whence the difference of longitude between the origin of coordinates and the point of maximum $=(+293{\cdot}8 \text{ miles} \times \sec 52^\circ{\cdot}19'=+481'=)+8^\circ{\cdot}01'$:

$\bar{y}=-4{\cdot}07$; whence the difference of latitude between the origin and the point of maximum $=-40'{\cdot}7$.

The geographical position of the maximum therefore is 52° 19′ N., and 268° 01′ E. The angle which the major axes make with the parallel of geographical latitude is $\frac{180-46^\circ\ 10'}{2}=66^\circ\ 55'$; and the values of the semi-axes of the ellipse of 1·875 are 223 and 85 geographical miles respectively.

The line of 1·875 has been drawn first on a map on a plane projection, and then transferred to the map on the polar projection which accompanies this memoir. The lines more distant from the maximum, viz. those of 1·850 and 1·800, have been drawn by the hand without the employment of calculation, and in such accordance with the observations as could be judged by the eye. The intensities entered in the map, and by which the lines have been drawn, are those of 192 stations. They include all the stations at which the total Force has been computed in the arbitrary scale, and inserted in the general table, No. XLVIII., except at 15 stations, where there is reason to believe that local disturbance prevailed to a considerable amount. The values of the total Force are derived from horizontal and statical ratios in the United States, and from statical ratios only in the countries to the north, where the Inclination became so great as to introduce an element of much uncertainty in the deduction of the total Force from its horizontal component. The intensities at four stations on the western side of the continent, on the shores of the Pacific, are introduced from the observations of Sir Edward Belcher, discussed in the IVth number of these Contributions. The line of 1·7, distinguished by a different character from that in which the other lines are drawn, is taken from the map (already referred to) in the Reports of the British Association for 1837, and is introduced into the present map for the purpose of affording a more ready means of comparing the form and geographical position of this line, with those of the lines inclosed within it, which are now for the first time delineated from observations, all of which have been made subsequently to the period when the map from which the line of 1·7 is taken was published. The accordance of the earlier and more recent observations is thus distinctly brought into view; and it will be perceived that the modifications, if any, which the line of 1·7 will require, will be very slight. With respect to the geographical position of the point of maximum of the Force, as it has been now computed from seventy-eight stations visited in 1843 and 1844, and surrounding the maximum in all directions, the coincidence with the central point of the closed curve of 1·7, as drawn in the map of 1837, could scarcely have been more perfect.

Materials for the extension of the isodynamic lines to the north and east of the present survey will shortly be supplied,—to the north by the Expedition under Sir John Franklin,—and to the east by Lieut. Moore of the Royal Navy, whose magnetic observations in Her Majesty's ship Terror form an important portion of the Survey accomplished by the Expedition under Sir James Ross; and whose subsequent observations in the Pagoda, in conjunction with those of Lieut. Clerk, R.A., in the completion of that survey, will form the VIIIth number of the Contributions. Under the direction of the Lords of the Admiralty, Lieut. Moore has proceeded in the present summer to Hudson's Bay, in one of the vessels of the Hudson's Bay Company in which a passage has been kindly granted him, for the purpose of obtaining a suite of determinations intermediate between those which form the subject of the present communication, and those which are now in progress by the officers of the Arctic Expedition. The magnetic lines surrounding the one of the two points of maximum intensity which is on British territory, will thus be completely delineated: and I may be permitted to express a hope, founded on the unsparing liberality of the Russian Government in other branches of magnetical research, that the lines which surround the other point of maximum intensity in the northern hemisphere, which is within the Russian dominions, may ere long be determined with an equal completeness. The geographical longitude of the Siberian maximum is approximately known from the observations of Hansteen, Due and Erman; but an equally correct knowledge of its latitude appears to require an extension of the researches to the shores of the Polar Ocean.

The intensity of the magnetic Force at its point of maximum in North America is 1·878 in the arbitrary scale; or 14·21 in absolute measure, of which the units are,—of mass a grain, of time a second, and of space a foot, in British weights and measures.

The intensity of the Force near the corresponding point in the southern hemisphere may be taken approximately, from a group composed of the daily determinations made by Sir James Ross's Expedition from the 19th to the 27th of March 1841, between the latitudes of −58° and −64° 26′, and longitudes of 128° 40′ E. and 148° 20′ E., the track of the Expedition when crossing the southern isodynamic ellipse of 2·000 about midway between the extremities of its principal axis. The mean of the results of this group is 2·059, or in round numbers, 2·06 in lat. −64° and long. 137°·5, or in absolute measure 15·60. Neither the position of this maximum, nor the value of the Force, can be regarded as determined with as much precision as we may consider those at the northern maximum now to be; but we may conclude with certainty, that at the present magnetic epoch the Force at the southern maximum is considerably greater in amount than at the northern, and that its position is in a somewhat higher geographical latitude than the corresponding point in the north; as is also apparently the southern point of 90° of Inclination; and probably also the position of the minor maximum of Force. If however we take a general view of the isodynamic lines in the two hemispheres, we see reason to believe that the difference under notice is rather a consequence of a different distribution of Force, than of an actual disparity in the magnetic charge of the two hemispheres. The two points of maximum in the south being nearer together at the present epoch (*i. e.* their shortest distance apart being less) than in the north, the intensity of the Force at both is raised, and a greater inequality is produced in the intensity on opposite sides of the southern hemisphere, than is the case in the northern hemisphere.

The progress of secular change, as it may be inferred from the comparison of the earlier and more recent observations of the Declination and Inclination, is tending to bring the two points of maximum in each hemisphere nearer to each other; whilst this progressive approximation continues, we may expect that the Force in each hemisphere will become more and more unequally distributed, and that the intensity at each of the four points of maximum will augment. The increase or decrease of the distance in geographical longitude between the two points of maximum in a hemisphere appears to be chiefly occasioned by the rapid secular change in respect to locality (or the rapid movement in translation) which the phenomena of the minor system undergo. The minor maximum was probably at its greatest elongation (180° of geographical longitude) from the major maximum in the *northern* hemisphere, some time in the last century. At that epoch therefore the distribution of Force in that hemisphere made its nearest approach to equality; the opposite geographical longitudes had the minimum of dissimilarity in their respective intensities, and the values of the Force at the major and minor maxima were respectively lower than at any other epoch. In this conclusion I have omitted the subordinate consideration of the influence which the distribution of the Force in the southern hemisphere exercises on the northern intensities, which is distinctly perceptible even in the middle magnetic latitudes, and adds to the complication of the phenomena of progressive motion occasioned by secular change. The influence of the one hemisphere becomes of course more and more effective on the phenomena of the other, as the line which separates the magnetic hemispheres is approached: it is this circumstance which renders the phenomena in the equatorial regions of the globe so much more complicated than elsewhere, so much more difficult to disentangle, and consequently so much less suited to conduct readily to a comprehension of laws. It has been justly said that meteorological phenomena should be studied, in the first instance, in the tropical rather than in the temperate zones, because they present themselves under a simpler aspect: the contrary is true in respect to the magnetical phenomena, both in the distribution of the Force at a particular epoch, and in the order and succession of secular changes, which nowhere appear so complicated as in the lower magnetic latitudes, where they cannot be understood unless the magnetic state of both hemispheres is taken into the account.

The coincidence of two or more points of maxima, (whether in the same or in different hemispheres,) under one and the same geographical meridian, may constitute *magnetic epochs*, which in the future history of the science may create an interest which can be very little conceived at present. The first conjunction of this kind, which our present purely empirical knowledge permits us to anticipate, is that of the *two minor maxima*, which, if the same progress of translation should continue that appears to have taken place in the last two and a half centuries, will hereafter be found on the same geographical meridian, and on the same side of the globe. Accompanying the movement of the two minor maxima of Force, the remarkable closed systems of the Declination lines, which are now found respectively in Siberia and in the Southern Pacific, by a movement of translation corresponding to that which they have undergone in the last two centuries, will also be found hereafter in the same geographical meridian, and will then doubtless have experienced a considerable modification of their form.

If we connect the two points of 90° of Inclination, the one in the northern and the other in the southern hemisphere, by an arc of a great circle crossing the terrestrial equator in the Atlantic Ocean, and if we examine the Inclination and Force along this arc, we shall find that the portions in which the Force *decreases* whilst the Inclination *increases*, amount to nearly a *third* of the whole distance between the points of 90° thus measured along the surface of the globe. Not only therefore is the once-supposed law, according to which the magnetic Force should everywhere increase in a certain expressed ratio with the increase of the magnetic latitude, inapplicable to the phenomena, but the modification which has latterly been substituted,—"*the law*," as it has been lately expressed, "of the *general* increase of the magnetic Force with the magnetic latitude,"—seems scarcely justified by the facts; and it may be doubted whether this expression is not more likely to mislead, by perpetuating the erroneous hypothesis in which it first took its rise, than to be of advantage as an empirical law, where the exceptions are so considerable. It is obvious that a too hasty generalization from observations made in those regions of the globe where the Force decreases with the increase of the dip, (as for example in the twenty degrees of latitude, or thereabouts, in North America, comprised between the point of maximum of the Force, and the point of 90° of Inclination,) might have appeared to justify an inference which would have been the direct contrary of the above-mentioned law. There is in fact no such connection between the Inclination and the Force as will justify the one being spoken of as an immediate function of the other, or will sanction a *general* statement, that the increase of the one is to be looked for from the increase of the other, or *vice versâ*.

I have generally preferred, in these Contributions, the employment of the expressions "line of no Inclination" and "position or point where the Inclination is 90°," to the more technical designations of "magnetic equator" and "magnetic pole," because I have noticed that, since it has been known that the locality of the dip of 90° is not that of the maximum of Force, and that the line of no Inclination is not that of least intensity, an ambiguity has prevailed in the use of the technical expressions, which has frequently been prejudicial to a clear understanding of the passages in which those terms are employed. It would not be difficult to show, in the recent writings even of persons actively engaged in the advancement of magnetical science, instances in which the term "magnetic pole" is used, where it can have no other meaning than that of a point of greatest intensity; and other instances in which the meaning is doubtful in itself, and is not cleared by the context. The line of no dip is also frequently confounded with that of least intensity, although they represent different phenomena, and occupy different positions on the globe. By some authors the terms "pole of intensity" and "pole of verticity" have been introduced, by which ambiguity is indeed avoided; but, whilst the term "pole" is retained, it must be admitted that in one of the two instances at least, it is used in a sense which (whatever may have been its earlier signification) is inconsistent with modern definition from high authority (that of M. GAUSS), and with that general understanding of its meaning, which has grown up under the hypothesis, imagined by some natural philosophers and now known to be erroneous, that the magnetism of the globe is analogous to that of a sphere of soft iron rendered magnetic by induction. The points of maximum of Force have also been called "foci" or "centres of Force," terms however which have not been suffered to pass without objection. In papers strictly limited as these Contributions are to investigations into the facts of terrestrial magnetism, I have thought it preferable to employ expressions, which although they may have the real disadvantage of appearing somewhat awkward, especially when they come to be frequently repeated, are subject to no ambiguity, and are obviously unconnected with any hypothesis.

In advocating the consideration which, in a general view of the earth's magnetism, appears to be due to the points in each hemisphere which form the centres of the systems of isodynamic lines, and are themselves points of greatest Force,—and to the circle or curve which encompasses the earth and unites the points in each geographical meridian where the magnetic force is weakest,—I am far from desiring an undue importance to be attached to them, over the points where the needle is vertical (or its inclination is 90°,) and over the line where the direction of the needle is horizontal (or is parallel to the surface of the earth). No general view of terrestrial magnetism is just, or is agreeable to our present knowledge, of which the characteristic features of both phenomena, both of the Inclination and of the Force, do not form a part. In purely magnetical relations indeed,—and remembering that as yet there is no connection established between polar and gravitating forces,—the points of the earth's surface, where the action of the magnetic forces is most intense, have, as it appears to me, an importance beyond those where the magnetic direction, the resultant of those forces, may happen to coincide with the direction of the gravitating force. In like manner, I consider that the line of least intensity, (or the line on which in every meridian the magnetic Force, having progressively diminished from the high latitudes of the one hemisphere, attains a minimum, and commences a progressive increase to the high latitudes of the other hemisphere,) deserves to be considered as the separating line between the northern and southern *magnetic* hemispheres, more properly than does the line in which the resultant direction of the magnetic forces happens to be perpendicular to the direction of the gravitating force. It may be a question whether this association of the phenomena of independent forces may not have been too exclusively dwelt upon, and have thus become in some respects prejudicial to the advancement of terrestrial magnetism; but the view of the philosopher is imperfect, who, in the contemplation to which he subjects the magnetic phenomena, in the hope of being conducted by the sure path of induction to a knowledge of their laws, omits to give a due consideration, either to those relations which have the advantage of being purely magnetical, or to those coincidences or contrasts which the magnetic phenomena may present in respect to the phenomena of gravitation, or to those of any other of the great physical agents at the surface of our planet.

Magnetic Inclination.

The observations of the Inclination made in Lieut. Lefroy's survey are contained in § 12. The number of determinations amounts to 179 (including 8 by Lieut. Younghusband, R.A. with the same instruments, and 5 by Dr. Rae, an officer of the Hudson's Bay establishment, furnished with an Inclinometer by Barrow), and the number of stations to 162. The general table, which includes the Inclinations observed by gentlemen of the United States, contains 450 determinations made at 335 stations. These were all observed between the years 1835 and 1846, and by far the greater number between 1839 and 1846. I have not attempted to introduce a correction for secular change, as the difference of epoch is small, and the rate of secular change is far from being even approximately known: without doubt also it varies in different parts of the wide district comprehended in this survey. At Toronto, its amount is so extremely small as to be scarcely appreciable by means of the most careful and multiplied observations continued for several years. The earliest observation of the Inclination in the United States, from which a satisfactory conclusion in respect to secular change may be derived, appears by Mr. Loomis's investigation[*], to have been made by myself in 1822, in the garden of the Lunatic Asylum, near New York. By comparing the result which I then obtained (73° 05′) with those of Locke, Lefroy and Renwick, at the same spot in 1841, 1842 and 1844 (72° 42′·5), we find a diminution in twenty years amounting to 22′·5, or rather more than 1′ annually. We may therefore presume from these instances, that the error in strict comparability, arising from the omission of a correction for secular change in the observations combined in this survey, the greater part of which differ not more than one or two years from a mean epoch, must be within the limits of the ordinary errors of observation, including of course those of station error.

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[*] Silliman's Journal, 1842, Art. IX. I believe that I may also claim the credit of having made in the same year the earliest determination of the magnetic force in the United States.

The method of computing the direction of the isoclinal lines, and the geographical distance between adjacent isoclinals representing certain differences in the amount of the Inclination, by a combination of the observations distributed over a limited district of the earth's surface, was first proposed by Dr. Lloyd in the Magnetic Survey of Ireland: it is simple and convenient when the lines conform to the conditions of being straight, parallel, and equidistant; but the problem becomes complicated and the calculation laborious in proportion as these conditions are departed from, and the number of indeterminate constants increases; until at length both complication and labour become excessive. In the parts of the continent of North America under consideration in this memoir, the variation of the isoclinal lines from the simple form above described is considerable: they are not straight lines on any projection; they are not parallel, nor are they equidistant. I endeavoured, nevertheless, to make the method of calculation answer, by breaking up the whole survey into several districts, and computing for each the coefficients of latitude and longitude, together with a central dip: but when districts were taken sufficiently small to satisfy approximately the required conditions of straightness, parallelism and equidistance, irregularities of observation arising from station error and other causes became significant, and materially influenced the results of the combination. I found myself obliged therefore finally to revert to the graphical method which I employed for the isoclinal lines of the British Survey, and which may be described as follows.

The observations are first entered in a Mercator's map on a sufficiently large scale, a small cross being made to mark the spot of observation in its proper latitude and longitude, with the value of the Inclination written by its side. The isoclinal lines corresponding to degrees are then drawn roughly by the eye as the observations appear to direct. Lines are next drawn through each place of observation perpendicular to the direction of the isoclinal lines at the spot, and distances are set off on them corresponding to the value in geographical miles of the number of minutes which the observed dip is either above or below the full degree to which it is nearest. The value in geographical miles corresponding to the odd minutes is computed proportionally to the distance between the two isoclinals on either side of the place of observation; and it is set off, from the cross which marked the station, towards the isoclinal of the full degree which is nearest to the observation. A cross is then made in a different coloured ink, to mark the spot where the observation places its nearest isoclinal line; it is obvious that if there were no irregularities in the observations, the isoclinal lines would run continuously through these new points. Finally, the original rough draft of the lines is revised in reference to these points, and such corrections are made in the tracing of the lines as may appear to be required. Observations which, from station error or otherwise, cause their mark to fall amongst those of a different degree from themselves, are given a distinctive sign, so that they do not mislead, whilst at the same time they are kept in view. The number of stations where local influences of this magnitude were found to prevail, amounts to eleven in the 335 stations at which the Inclination is determined in this memoir.

By this process each isoclinal line is deduced independently of those on either side of it, and distinctive features in each are shown, whether resulting from the general system or from district anomalies.

The northern observations of Lieut. Lefroy extend so far to the westward that they overlap the meridians of some of the stations of Sir Edward Belcher, reported in the IVth Number of these Contributions. I have therefore included the four following stations of Sir Edward Belcher in this Map, and the isoclinal lines of 70° and 76° are thus carried across the whole continent of America from sea to sea.

	Latitude.	Longitude.	Inclination.
	° ′	° ′	° ′
Port Etches	60 21	213 19	76 02·9
Sitka.	57 03	224 36	75 49·1
Baker's Bay	46 17	235 58	69 26·7
Fort Vancouver . . .	45 37	237 24	69 22·2

The lines drawn on the Mercator's map have been transferred to the map on the polar projection which accompanies this memoir; and for the purpose of more readily computing the inclination at any geographical position within the limits of the survey, corresponding to the observations combined in drawing the lines, the following Tables have been formed, which show the value of the Inclination at the intersection of every degree of latitude, with every fifth degree of longitude between the longitudes of 231° and 261°, and with every 2½ degrees between those of 261° and 291°. The use of these Tables seems too obvious to need an explanation; by the usual process of interpolation, the Inclination due to any geographical locality within the bounds of the survey may be obtained by a very light calculation: a formula which should give the same result would necessarily consist of a considerable number of terms, and would therefore be of less practical utility.

Table VI.—Showing the values of the Inclination at the intersection of each degree of latitude from 38° to 48°, with every 2½° of longitude from 268° 30′ to 291.

Lat.	Longitudes.										Lat.
	268° 30′.	271°.	273° 30′.	276°.	278° 30′.	281°.	283° 30′.	286°.	288° 30′.	291°.	
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°
38	68 46	69 01	69 21	69 40	69 57	70 14	70 22				38
39	69 43	69 57	70 17	70 36	70 52	71 09	71 16	71 18			39
40	70 39	70 53	71 13	71 31	71 47	72 03	72 09	72 11			40
41	71 34	71 48	72 08	72 26	72 42	72 57	73 01	73 03	73 08		41
42	72 28	72 43	73 03	73 21	73 36	73 50	73 53	73 54	73 58		42
43	73 21	73 37	73 57	74 15	74 30	74 42	74 44	74 45	74 47		43
44	74 13	74 30	74 51	75 09	75 22	75 32	75 34	75 34	75 34		44
45	75 04	75 22	75 44	76 02	76 13	76 21	76 22	76 21	76 20	76 12	45
46	75 54	76 13	76 36	76 50	77 02	77 07	77 06	77 09	77 06	76 57	46
47	76 43	77 03	77 23	77 37	77 45	77 49	77 50	77 53	77 44	77 36	47
48	77 32	77 54	78 08	78 22							48

Table VII.—Showing the values of the Inclination at the intersection of each degree of latitude from 47° to 66°, with every 5° of longitude from 231° to 261°, and with every 2½° of longitude from 261° to 268° 30′.

Lat.	Longitudes.										Lat.
	231°.	236°.	241°.	246°.	251°.	256°.	261°.	263° 30′.	266°.	268° 30′.	
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	°
47	70 09						75 33	75 59	76 22	76 43	47
48						75 26	76 20	76 47	77 10	77 32	48
49					75 15	76 12	77 08	77 34	77 58	78 20	49
50				75 00	76 00	76 58	77 54	78 21	78 44	79 07	50
51				75 45	76 44	77 43	78 40	79 06	79 29		51
52			75 26	76 29	77 29	78 27	79 25	79 50	80 14		52
53		75 08	76 09	77 12	78 13	79 11	80 09	80 34	80 56		53
54	74 53	75 50	76 51	77 54	78 56	79 54	80 48	81 17	81 39		54
55	75 36	76 32	77 33	78 37	79 38	80 37	81 27	81 59	82 21		55
56	76 18	77 14	78 15	79 19	80 20	81 19	82 12	82 40	83 04		56
57	76 59	77 55	78 56	79 59	81 01	81 56	82 51				57
58	77 40	78 35	79 36	80 40	81 42	82 35					58
59	78 19	79 14	80 15	81 20	82 22						59
60	78 58	79 53	80 54	81 59	83 01						60
61	79 36	80 31	81 32	82 38	83 39						61
62	80 14	81 09	82 10	83 16							62
63	80 51	81 36	82 48	83 53							63
64	81 28	82 23	83 24								64
65	82 05	83 00									65
66	83 31										66

To give some idea of the degree of correctness with which these tables (particularly in the portion of the survey which is most likely to be referred to) may be considered to represent the observations from which they are derived, and to give consequently the true Inclinations corresponding to geographical positions, I have formed groups in localities where observations are much clustered, and have compared the tabular Inclination corresponding to the mean latitude and longitude, with that resulting from the mean of the observed Inclinations: the comparison shows as follows:—

Table VIII.

Group.	Long.	Lat.	No. of observations.	Mean of the observed Inclinations.	Computed tabular Inclinations.	Tabular in excess or defect.
1.	269° 26′	42° 28′	14.	73° 00′·1	72° 59′	−1′
2.	269 59	38 49	8.	69 38·7	69 41	+2
3.	275 36	38 30	6.	70 06·1	70 05	−1
4.	275 19	46 21	10.	77 05·2	77 06	+1
5.	278 30	41 18	15.	72 59·0	72 59	0
6.	285 58	40 59	11.	73 01·3	73 02	+1
7.	288 49	42 13	11.	74 11·1	74 09	−2
8.	291 20	46 06	12.	77 01·4	77 00	−1

The tabular inclination corresponding to the geographical position of Toronto is 75° 13′·5. Dr. Locke's observation in 1843 was 75° 13′·4. The needles of the observatory gave a mean inclination for that year amounting to 75° 16′. The mean of the last year (1845) is 75° 15′·5. So far as the absence of station error is an object in the choice of a situation for a magnetic Observatory, the site of the Toronto Observatory appears to have been happily chosen.

Taking single stations, there are seven at which the tabular dip differs more than 1° from the observed; at five of these the observed is in excess of the tabular, and at two in defect. The five are,—Kingston in Canada; Otter Island on Lake Superior; two stations 500 feet distant from each other in the Magnetic Inlet, and one on the adjacent isthmus on the south side of Lake Superior. The two in defect are Chat Falls on the Ottawa River; and the Portage Ecarté, near Lake Superior, towards the height of land which separates the waters which flow into Lake Superior from those which flow towards Lake Winnipeg. At all these stations the observations of the magnetic Force, as well as those of the Inclination, manifest the existence of local disturbing influence. At Chat Falls the Inclination is in defect and the Force in excess; at Otter Island the contrary is the case, the Inclination being in excess and the Force in defect. At Portage Ecarté, both Inclination and Force are in defect; and at the three other stations both elements are in excess. Besides the seven stations where the station error appears to exceed 1°, there are four (Isle d'Urval and Kingsey in Canada; Pierre au Calumet on the Elk River; and the Eagle River, in the same mineral district on the south side of Lake Superior as the magnetic inlet) at which the observations appear to be affected by station error to an amount which is less than 1°, but is still considerable. At each of these four stations the observed dip is in excess. The Inclinations at the eleven stations which have been thus named, are omitted in the map accompanying this memoir: they are eleven out of 335 stations. Of the remaining 324 stations there are some at which local disturbance of a less amount may be inferred; but all these are inserted in the map. Four of the eleven omitted stations are in a district, rich in minerals, on the south side of Lake Superior, near the 272nd geographical meridian: in each of these four instances the effect of the disturbance has been to increase the Inclination, but there are other stations in the same district where the observed Inclination does not materially differ from that which is due to the geographical position; and there is one station (United States Agency) where it is some minutes in defect. In the cases referred to, the influence of the disturbing causes is rather to produce irregularity at individual stations, than a systematic derangement of the general direction of the magnetic lines, similar to the highly interesting phenomenon in the northern part of Bohemia, recently investigated by M. Kreil*; from which investigation we learn that a more systematic relation may exist in some localities between geological and magnetical phenomena than had been previously apprehended. But instances of disturbance even at individual stations in the countries included in this survey are so unusually rare, that we should the less expect to find districts exhibiting a systematic affection: of such I can perceive no traces; the direction of the lines conforms to the general magnetic system of the globe, and appears to suffer no material interruption; such district anomalies either do not exist, or the observations have not brought them to light.

Determinations of Latitude and Longitude.

The geographical positions of the stations visited by Lieut. Lefroy in 1843 and 1844 are given in Table IX., with the authorities on which they depend: the latitudes and longitudes entered in the column headed 'observed' were either determined by his own observations, or reduced by himself by courses and distances from neighbouring stations of observation: to distinguish those stations at which the latitude or longitude was observed on the spot, a mark is inserted in the adjoining column: the mark ⊙ indicates latitude observed by meridian altitude of the sun; the mark * by altitudes of Polaris: in the column of longitudes, the mark ⊙ indicates chronometrical longitudes deduced from observations of the sun's altitude; and the mark * from altitudes of a star: where no mark is inserted, the latitude or longitude was deduced by observation of courses and distances from the adjacent stations. The chronometrical longitudes are dependent upon the longitudes of the following principal stations, as given by Sir John Franklin, Captain Bayfield, and others: viz.

Fort William	89° 27'	Bayfield.
	89 16	Franklin.
	89 23	Tiarks.
	89 22	Mean
Sault St. Mary . . .	84 34	Bayfield.

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* Magnetische und Geographische Ortsbestimmungen in Böhmen; Prag. 1846.

	°	′		
Fort Frances	93	28·6	Franklin.	
Fort Alexander . . .	96	21·4	Franklin.	
Norway House . . .	98	7·1	Taylor*.	
York Factory . . .	92	26·0	Franklin.	
Cumberland House .	102	19·4	Franklin.	Mean of two determinations.
Carlton House . . .	106	12·7	Franklin.	
Isle à la Crosse . . .	107	53·8	Franklin.	Mean of two determinations.
Athabasca	111	18·7	Franklin.	Mean of two determinations.
Fort Simpson . . .	121	25·0	Franklin.	Mean of two determinations.

These longitudes were determined with a greater number of chronometers than were carried by Lieut. Lefroy, and in some instances are the mean of determinations made by Sir John Franklin in his two journeys; the stations were selected therefore as points of departure; observations were made there with peculiar care, and the longitudes of intermediate stations, taken en route, were calculated from them successively. From July 1843 to September 1844 Lieut. Lefroy had the use of one chronometer only, (the other having met with an accident,) and it was found too irregular in its going to be relied on for long periods. The longitude was determined by lunar distances at certain stations, which are given in the Table.

Wherever a station of observation is common to Sir John Franklin and Lieut. Lefroy, the latitude or longitude determined by the former officer is inserted for comparison in the column headed "from other determinations," which also contains values taken by measurement from the maps which accompany the narrative of his journeys. Lieut. Lefroy's observations along Peace River, and from thence by Lesser Slave Lake to the Saskatchawan, a line which was not taken by Sir John Franklin, are the first, it is believed, that have been published since those of Sir Alex. Mackenzie, and materially correct the course of that river, as laid down on the best maps.

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[*] Late Hudson's Bay Company's surveyor. This longitude is the mean of five observations of Jupiter's satellites, the extreme difference amongst them being 11′ 10″.

Table IX.

General Table of the Latitudes and Longitudes of the Stations visited by Lieut. Lefroy in 1843 and 1844.

Station.	Observed.				From other determinations.		Remarks.
	Latitude.		Longitude.		Latitude.	Longitude.	
	° ′		° ′		° ′	° ′	
Montreal	....	....	....	....	45 31 (*a.*)	286 25 (*a.*)	(*a.*) From a map in
Isle d'Urval	....	....	....	....	45 24 (*a.*)	286 14 (*a.*)	the Quart.-Master
La Combes	....	....	....	....	45 32 (*a.*)	285 51 (*a.*)	General's office in
Island in the Ottawa River	45 36·4	*	285 38	⊙			Canada.
Entrance of Grenville Canal	45 36·0	....	285 28	⊙			
Chatham	45 36·2	⊙					
Pte aux Chênes	....	....	....		45 37 (*b.*)	285 05 (*b.*)	(*b.*) from a map published for the Ca-
Alfred Township	....	....	284 48	⊙	45 37 (*b.*)		lished for the Ca-
Foxes Point	....	....	....	....	45 32 (*b.*)	284 26 (*b.*)	nada Company in
Templeton's Farm	....	....	284 48	⊙	45 29 (*b.*)		1829.
Point Aylmer	45 15	*	284 02	⊙			
Chat Portage	....	....	....	....	45 26 (*b.*)	283 28 (*b.*)	
Fort Portage	45 36	....	283 07	⊙			
Décharge d'Argile	45 39·6	⊙					
Grand Calumet	45 45	....	283 20				
Fort Coulange	45 54·9	⊙	282 56	⊙			
Pointe Baptême	....	....	....	....	46 06 (*c.*)	282 34 (*c.*)	(*c.*) From Wylde's
Portage des deux Joachims	46 12	⊙	281 41				Map, 1843.
Roche Capitaine	46 17·2	*	281 42	⊙			
Trou Portage	46 15·0	....	281 27				
Matawa	46 18·0	....	281 20	⊙			
Little River, 1st Portage	46 18·5	....	281 17				
Lake Temisique	46 18·0	⊙					
Lac du Grand Vase, South side.	46 18·5	....	280 34	⊙			
Portage du Grand Vase	46 19·5	....	280 26	⊙			
Lake Nipissing	46 14·0	⊙	280 01				
French River	45 58·0	⊙	279 25				
Ricolet Falls	45 57·0	....	278 59				
Pte au Croix	45 55·5	⊙	278 42	....	....	....	Mouth of French
Lake Huron	46 00	....	278 10				River.
La Cloche	46 07	*	277 32	*			
Snake Island	46 10	....	277 10				
Cranberry Bay	46 11	....	276 57				
Near Mississauga	46 08	*	276 50	*			
Tessalon Point	46 16	....	276 29				
St. Mary's River	46 20	*	276 04	*	....	275 30 (B.)	Campment d'Ours.
Sault St. Mary	46 30·7	⊙	....	....	46 31 (B.)	275 26 (B.)	(B.) Capt. Bayfield,
Pointe aux Pins	46 29·3	*	....	....	....	275 19 (B.)	R.N.
Pointe au Crêpe	....	....	275 02	⊙	46 58 (B.)	275 07 (B.)	Near Mamainse.
Gargantua	47 37·2	⊙	274 49	⊙	....	274 45 (B.)	
Fort Michipicoton	47 56·0	*	274 53	⊙	....	274 55 (B.)	
Near Chienne River, one mile E.	47 52·0	....	274 36	⊙	....	274 35 (B.)	
Otter Island	....	....	....	....	48 07 (B.)	373 45 (B.)	
One mile below White River	48 31·6	⊙	273 27	⊙			
White River	48 33·3	⊙	273 27	⊙	....	273 33 (B.)	
Fort Pic	48 38·0	⊙	273 29	⊙	....	273 31 (B.)	
Terreplatte	48 49·0	⊙	272 15	⊙			
Near Thunder Bay	48 20·3	⊙					
Near Pointe Tonnerre	....	....	....	....	48 19·0 (B.)	270 58 (B.)	(*d.*) Bayfield 270 33
Fort William	48 23·6	⊙	....	....	....	270 38 (*d.*)	Franklin 270 44
Portage Ecarté	....	....	....	....	48 25 (B.)	270 15 (B.)	Tiarks 270 37
Portage de l'Isle	....	....	270 22	⊙	48 26 (F.)		
Bad Portage	....	....	270 20	⊙	48 29 (F.)		Mean 270 38

TABLE IX. (Continued.)

Station.	Observed.				From other determinations.		Remarks.
	Latitude.		Longitude.		Latitude.	Longitude.	
	° ′		° ′				
Chien Portage					48° 39′(F.)	270° 26′(F.)	
Chien Lake	48 47·0		270 20				
Chien Lake	48 50·9	⊙					
Prairie Portage					48 57(F.)	269 59(F.)	(F.) Captain Sir JOHN FRANKLIN, R.N.
Savannah Portage			269 52	⊙	48 53(F.)	269 57(F.)	
French Portage	48 35·0					268 53(F.)	
Portage des Morts	48 35·0		268 27	⊙			
Portage des deux Rivières	48 34·5	⊙				268 33(F.)	
Lac à la Crosse	48 24·0		267 50	⊙			
Lac à la Crosse	48 21·3	⊙					
2nd Portage from Lac à la Crosse	48 14·6	⊙	267 33	⊙		267 36(F.)	
Sturgeon Lake	48 27	⊙					
Sturgeon Lake	48 28		267 27			267 26(F.)	
Portage	48 29		267 19	⊙			
Lac la Pluie	48 32·5	⊙	267 04	⊙			
Fort Francis	48 37·2	⊙			48 36(F.)	266 31(F.)	
Rainy River	48 47·7	⊙	265 29	⊙			
Lake of the Woods	49 05·0	✳	264 59	⊙			
Lake of the Woods	49 19·0		265 18	⊙			
Lake of the Woods	49 28·7	⊙					
Lake of the Woods	49 28·0		265 20				
Rat Portage	49 46·5	⊙	265 21	⊙	49 45(F.)	265 33(F.)	
Winnipeg River	50 10·1	⊙	264 50	⊙			
Burnt Portage	50 19·0	✳	264 24	✳		264 20(F.)	
Slave Portage	50 10·6	⊙	264 23			264 18(F.)	
Barrier Portage	50 06·0		264 27	⊙		264 16(F.)	
Portage in Pinnaway River	50 12·0		263 57	⊙			
Cap Lake	50 20·8	⊙					
Fort Alexander	50 37·1	⊙				263 39(F.)	
Lake Winnipeg	50 27·3	⊙	263 22	⊙			
Upper Fort Garry	49 53·1	⊙	262 57	⊙			
Mouth of Red River	50 19·0	✳	263 19	⊙			
Lake Winnipeg, West side	51 03·6		263 15	⊙			
Lake Winnipeg, East side	51 04·0	⊙	263 39				
Ox Island	51 16·5	✳	263 32	✳			
Lake Winnipeg	51 34·0	✳	263 18	✳			
Lake Winnipeg	51 38·0	✳	263 12	⊙			
Lake Winnipeg	51 44·5		263 12	⊙			Nearly opposite Tête du Chien.
Lake Winnipeg	51 45·3	⊙	263 07				
Lake Winnipeg	52 21·0	⊙	262 51	⊙			Near Berens River.
Lake Winnipeg	52 22·6	✳	262 51				
Lake Winnipeg	52 29·0		262 47				
Poplar Point	52 56·0	⊙					
Old Norway House					53 41·6(F.)	261 59(F.)	
Norway House	53 58·9	⊙				261 53(*e.*)	(*e.*) From five observations of Jupiter's satellites by the late Mr. TAYLOR.
Blackwater River	54 18·8	✳					
Carpenter's Lake	54 14·0		262 22	⊙			
Hairy Lake	54 20·0		262 50	⊙		262 36(F.)	
Echiamamis	54 21·0		262 55	⊙			
Painted Stone Portage	54 22·3	✳					
Whitefall Portage			263 34		54 24(F.)	263 29(F.)	
Holey Lake, East side	54 56·0		264 18	⊙			
Half mile below the Crooked Spout	54 43·9	⊙					
Oxford House	54 56·4	✳	264 30			264 32(F.)	
Rapid below Oxford House	54 52·8	⊙					
Knife Portage	54 53·2	⊙					
North side of Knee Lake			264 49	⊙	54 51(F.)		

TABLE IX. (Continued.)

Station.	Observed.				From other determinations.		Remarks.
	Latitude.		Longitude.		Latitude.	Longitude.	
Long Portage, Jack's River	55° 15′·0	⊙	265° 35′	⊙	55° 14′(F.)	265° 38′(F.)	
Creek Portage	55 24·6	⊙					
Morgan's Portage	55 29·0	....	266 08				
White Earth Portage	55 26·0	....	265 57	⊙	....	265 57(F.)	Station of July 21.
White Earth Portage	....	....	266 10	⊙	55 33(F.)	....	Station of July 31.
Shamatawa	56 21·0	....	267 04	....	....	267 00(F.)	
Five miles below Shamatawa	56 25·7	⊙					
York Factory	57 00·1	⊙	....	....	57 00·1	267 34(F.)	
Lake Winnipeg	....	....	260 55	⊙	....	....	M^{c}Intosh's Island.
Ditto, near first Rocky Point	53 31	⊙	260 48	⊙			
Saskatchawan River	53 11	⊙	....	....	....	....	Mouth of the River.
Grand Rapid	....	....	260 32	⊙	53 08(F.)	260 32(F.)	
Cross Lake, East side	53 10·2	⊙	260 28	⊙	....	260 23(F.)	
Hare Island, Cedar Lake	53 12·0	⊙					
Island in Cedar Lake	53 18·0	....	259 48	⊙			
Devil's Drum Island	....	....	259 15	⊙	53 19(F.)	259 20(F.)	Or Isle à Festins.
Four miles above the Pas	53 48	✱	258 32	⊙	....	258 37(F.)	
Cumberland House	....	....	....	....	53 57(F.)	257 41(F.)	
Pine Island Lake	54 14·3	⊙					
Crooked Rapid	54 24·7	⊙					
Beaver Lake	54 26·0	....	257 50	....	....	....	Limestone Point, at the S. entrance.
Half a mile north of Haye's River	54 44·0	⊙					
Carp Portage	54 47·2	....	257 21	⊙			
Pine Portage	....	....	....	....	55 04(F.)	257 18(F.)	
Frog Portage	....	....	....	....	55 27(F.)	256 30(F.)	
Little Rock Portage	55 34·3	....	255 26	⊙	....	255 27(F.)	
Great Devil's Portage, East end.	55 40·1	⊙	254 55	....	....	255 12(F.)	
Portage des Eçores	55 43·0	✱					
Trout Portage	55 42·5	....	254 31	⊙			
Harrier Portage	55 35·8	⊙					
Half a mile above Cardinal Rapid	55 39·1	✱					
Half a mile below Rapide qui ne parle pas	55 43·5	....	254 10	⊙			
Canoe Portage	55 42·7	⊙					
Pine Portage	55 43·2	....	....	....	....	254 04(F.)	
Snake Point	55 51·0	....	253 15	⊙			
Snake Rapid	55 45·7	⊙	....	....	....	253 30(F.)	
Portage Sonnante	....	....	252 34	⊙	55 54(F.)	252 24(F.)	
Isle à la Crosse	....	....	....	....	55 25(F.)	252 06(F.)	
Buffaloe Lake	56 04	....	....	....	....	251 20(F.)	
Long Portage on River de la Loche	56 14·9	⊙	250 42	⊙	....	250 55(F.)	
Portage de la Loche, East end.	56 34·5	✱	250 16	✱	....	250 23(F.)	
Portage de la Loche, West end.	56 43·4	✱	250 08	⊙	56 43(F.)	250 08(F.)	
Portage Terre Blanche	56 41·7	⊙					
Portage Gros Roche	56 43·5	....	249 51	⊙			
Cascade Portage	56 42·5	....	249 41	⊙	56 42(F.)	249 46(F.)	
Clearwater River	....	....	....	....	56 39(F.)	249 09(F.)	
Pine Island, Elk River	56 58·0	✱	....	....	....	248 54(F.)	
Pierre au Calumet	....	....	248 13	⊙	57 24(F.)	248 25(F.)	
P^{te} Brulée	....	....	....	....	58 07(F.)	248 35(F.)	
Athabasca	....	....	....	....	58 43(F.)	248 42(F.)	
Fort Good Hope	....	....	....	....	66 16(S.)	231 30(F.)	(S.) Observed by SIMPSON.
Rapide sans Sault	65 48	⊙					
Fort Norman	....	....	....	....	64 31(F.)	235 16(F.)	
Fort Simpson	61 51·7	⊙	....	....	....	238 45(F.)	
P^{te} Brulée	61 10·0	....	240 51	⊙			

TABLE IX. (Continued.)

Station.	Observed.				From other determinations.		Remarks.
	Latitude.		Longitude.		Latitude.	Longitude.	
	° ′		° ′		° ′	° ′	
Yellow Knife River	61 12·3	⊙					
Sandy Point	61 20·0	....	242 00	⊙			
Little Lake	61 25·7	⊙					
Big Island (Fishery)	61 11·7	....	243 22	⊙			
Big Island, East end	61 07·7	⊙					
Hay River	60 48	....	244 49	⊙	60 51(F.)	244 42(F.)	
Near Hay River	60 49	⊙					
Fort Resolution	61 10	⊙	....	....	....	246 15(F.)	
Buffaloe River	60 34	....	246 48	⊙			
Portage Grand Detour	60 22	....	247 00	⊙			
In ditto, First Lake	60 20·6	⊙					
Salt River (Slave River)	....	....	247 45	⊙	60 06(F.)	247 38(F.)	
Slave River	60 02·2	⊙					
Pelican Portage	....	....	248 09	⊙	59 58(F.)	248 09(F.)	
Peace River	58 55	⊙					
Point Providence	58 58	....	247 50	⊙			
Peace River	59 10·1	⊙	....	....	....	....	Amongst the Gypsum Islands.
Peace River	58 58	....	247 01	⊙			
Poplar Island	58 39	⊙	246 03				
Falls of Peace River	58 24·2	⊙	245 06				
Fort Vermilion	58 24·7	⊙	243 55	⊙			
Peace River	57 57·0	....	243 00	⊙			
Peace River	57 50·7	⊙					
Peace River	57 19·0	....	243 32	⊙			
Peace River	57 12·3	⊙					
Opposite River Cadotte	56 47·0	....	242 58	⊙			
Peace River	56 42·0	⊙					
Fort Dunvegan	55 55·6	⊙	241 35	⊙	....	....	By 2 sets of lunar distances, ☾ from sun west 241° 41′.
Riviere de Prairie	55 50·1	⊙					
Fort at Lesser Slave Lake	55 32·8	⊙	244 07	....	....	....	By 4 sets of lunar distances, 2 ☾ from *E., and 2 ☾ from ⊙ W. 244° 06′.
Cranberry Point	55 29·5	*	244 54	*			
Point Dejala	55 26·5	⊙	244 59	⊙			
On Lesser Slave Lake	55 15·6	⊙					
Junction of the Slave and Elk R.	55 13·0	....	246 10	⊙			
Elk River, opposite Pembina River	54 45·7	*					
Elk River	54 43·0	....	246 00	⊙			
Fort Assiniboine	54 19·7	⊙	245 32	⊙			
Paddle River	54 09·8	*	245 59	*			
Pembina River	54 08·0	....	246 06				
Edmonton	53 31·1	⊙	247 08	⊙			
Saskatchawan River	54 04·8	⊙	248 16	⊙			
Saskatchawan River	53 50·0	⊙	249 30	⊙			
Fort Pitt	53 34·0	*	250 41	*			
Saskatchawan River	53 07·0	⊙	251 30	⊙			
Saskatchawan River	52 23·2	⊙	252 56	⊙			
Carlton House	....	....	....	....	52 51(F.)	253 47(F.)	
Saskatchawan River	....	....	255 12	....	53 16(F.)		

§ 11. *Lieut.* Lefroy's *Observations of the Magnetic Force.*

These observations were of two kinds; those which were designed to determine the *absolute* value of the *horizontal component* of the force; and those which had for their object to determine the *ratio* of the *total* force at different stations. For the absolute determinations magnets of small dimensions were employed in portable apparatus, which will be hereafter described. The observations to determine the relative values of the total force were made with two needles on Dr. Lloyd's statical principle, used in Gambey's circle, and with two needles on Mr. Fox's principle, used in a circle of seven inches diameter. The Lloyd's needles were distinguished as L. A. and L. B.: the Fox's as F. A. and F. C. Experiments to determine the coefficient in the temperature corrections of these needles were made at Toronto in the first three months of 1843. The observations at high temperatures were made in the detached building of the observatory, which was heated for the purpose by a copper stove: those at low temperatures were made partly in the same room and partly in the open air outside the building. In Tables X. and XI., in which these experiments are recorded, v denotes the angle of deflection with a constant weight at the temperature t, in the experiments at low temperatures; θ the inclination; and φ the total force, which is $\frac{\cos v}{\sin(\theta - v)}$ with Dr. Lloyd's needles, and $\sin v$ with Mr. Fox's; v', θ' and φ' denote the corresponding values in the experiments at high temperatures. Then, q being the coefficient, $\varphi = \varphi' \left(1 - q\,(t - t')\right)$; and $q = \frac{\varphi - \varphi'}{\varphi'(t - t')}$.

Table X.

Abstract of the Observations made at Toronto to ascertain the value of q for the needles L. A. and L. B.

L. A..

Low temperatures.					High temperatures.				
1842 and 1843.	t.	v.	θ.	φ.	1843.	t'.	v'.	θ'.	φ'.
Dec. 10.	29·0	−36° 37′·0	75° 17′·2	0·86509	Jan. 9.	66·9	−36° 45′·9	75° 15′·4	0·86414
Jan. 13.	31·8	−36 41·9	75 13·9	0·86433	13.	54·4	−36 33·5	75 13·9	0·86506
13.	32·0	−36 34·5	75 13·9	0·86497					
17.	35·0	−37 17·2	75 13·4	0·86123	17.	61·8	−36 36·8	75 13·4	0·86472
30.	38·0	−36 38·8	75 16·5	0·86487	30.	65·4	−37 02·3	75 16·5	0·86284
Feb. 1.	25·6	−36 24·2	75 15·7	0·86604	Feb. 1.	62·3	−36 41·1	75 15·7	0·86459
2.	25·8	−36 31·7	75 15·7	0·86542	2.	79·0	−36 36·8	75 15·7	0·86499
3.	27·4	−36 39·5	75 15·6	0·86470	3.	80·2	−36 58·7	75 15·6	0·86311
4.	37·0	−36 54·9	75 15·6	0·86337	4.	76·4	−36 44·6	75 15·6	0·86431
10.	25·3	−36 37·0	75 14·7	0·86479	11.	71·9	−36 47·6	75 14·7	0·86387
10.	27·5	−36 37·0	75 14·7	0·86479	11.	64·5	−37 08·3	75 14·7	0·86215
	30·4	−36 41·2	75 15·2	0·86451		68·3			0·86398

Hence for L. A. $q = \cdot000016$.

L. B..

Low temperatures.					High temperatures.				
1843.	t.	v.	θ.	φ.	1843.	t′.	v′.	θ′.	φ′.
Jan. 17.	34·4	−33° 45′·1	75° 13′·4	0·87923	Jan. 17.	62·9	−33° 58′·2	75° 13′·4	0·87814
Feb. 1.	26·2	−33 35·1	75 15·7	0·88026	Feb. 1.	63·9	−34 12·5	75 15·7	0·87715
2.	25·8	−33 41·1	75 15·7	0·87976	2.	85·1	−34 18·7	75 15·7	0·87661
3.	27·8	−33 30·6	75 15·6	0·88062	3.	80·4	−34 14·6	75 15·6	0·87697
4.	37·5	−34 05·9	75 15·6	0·87765	4.	88·6	−34 20·1	75 15·6	0·87651
10.	27·7	−34 04·2	75 14·7	0·87776	11.	66·1	−34 04·3	75 14·7	0·87775
	29·9	−33 47·0	75 15·1	0·87921		74·5			0·87719

Hence for L. B. $q = \cdot 00005$.

Table XI.

Abstract of the Observations made with Needle F. A. and F. C. to determine the Coefficient for the temperature correction.

Needle F. A.

Weight.	1843.	Low temperatures.		High temperatures.		Weight.	1843.	Low temperatures.		High temperatures.	
		t.	v.	t′.	v′.			t.	v.	t′.	v′.
2·0 grs.	Jan. 4.	26°·0	21° 09′·9	60°·8	21° 17′·2	2·5 grs.	Jan. 4.	26°·2	26° 52′·2	61°·5	27° 11′·8
	4.	28·0	21 08·9	56·8	21 20·3		4.	27·4	26 45·9	57·1	27 18·1
	12.	35·2	21 12·3	74·2	21 19·5		12.	35·5	27 04·2	74·8	27 05·7
	12.	35·5	21 21·8	82·4	21 25·6		12.	35·4	27 00·3	80·0	27 11·3
	14.	30·6	21 09·5	71·5	21 32·1		14.	29·5	26 53·1	70·5	27 12·9
	14.	27·0	21 12·6	61·2	21 20·8		14.	26·0	26 58·8	62·1	27 02·1
	16.	33·5	21 10·0	72·7	21 25·9		16.	32·5	27 08·4	74·8	27 18·1
	Means..	30·8	21 12·1	67·4	21 23·1		Means..	30·4	26 57·6	68·7	27 11·4
3·0 grs.	Jan. 4.	26·7	33 05·0	61·2	33 17·2						
	4.	26·2	33 02·8	58·8	33 18·5						
	12.	35·5	33 21·6	75·9	33 26·0						
	12.	35·0	33 15·2	83·4	33 25·8	4·0 grs.	Jan. 12.	34·9	46 45·4	74·4	46 52·5
	12.	34·2	33 14·8				12.	34·0	46 42·1	80·3	47 05·6
	16.	32·5	33 07·4	78·2	33 15·6		16.	34·5	46 41·4	82·0	47 15·4
	Means..	31·7	33 11·1	71·5	33 20·6		Means..	34·4	46 43·0	78·9	47 04·5

Hence, giving the observations with 4·0 grains, half the weight of the observations with each of the other three weights, we have $q = \cdot 000164$.

Needle F. C.

Weights.	1843.	Low temperatures.		High temparatures.		Weights.	1843.	Low temperatures.		High temperatures.	
		t.	*r*.	*t′*.	*r′*.			*t*.	*r*.	*t′*.	*r′*.
2·0 grs.	Feb. 2.	24°·7	26° 32′	83°·0	26° 36′	2·5 grs.	Feb. 2.	28°·0	34° 06′	88°·0	34° 33′
	3.	32·7	26 47	83·5	26 49		3.	30·7	34 19	87·4	34 33
	3.	31·0	26 38	67·8	27 16		3.	29·5	33 54	70·1	34 24
	6.	29·0	26 54	82·0	26 58		6.	29·0	34 16	79·2	34 30
	6.	28·1	26 45	64·6	26 55		6.	28·2	34 15	64·0	34 30
	4.	28·2	26 42	64·5	26 42		4.	31·4	34 21	65·0	34 18
	Means. .	28·9	26 43	72·9	26 52·7		Means. .	29·5	34 12	75·6	34 28
3·0 grs.	Feb. 2.	24·0	42 45	89·0	42 43						
	3.	29·1	42 31	87·2	42 38						
	3.	28·5	42 37	70·5	42 35						
	6.	29·0	42 41	73·0	42 40						
	6.	28·1	42 43	62·2	42 47	1·5 gr.	Feb. 6.	28·5	19 39	82·1	20 12·0
	4.	33·7	42 42	65·0	42 56		6.	27·5	19 46	65·3	20 03·0
	Means. .	28·7	42 39·8	72·8	42 43·2		Means. .	28·0	19 42·5	78·7	20 07·5

Hence, giving the observations with 1·5 gr. one-third the weight of those with each of the other weights, $q=\cdot00013$; or, if we reject the observations with 3 grains, which are much more irregular than the others, $q=\cdot000175$. The value which has been employed is ·00016 for both needles F. A. and F. C.

It will perhaps be most convenient to give a brief history of each needle during the period comprised by the observations discussed in this memoir; beginning with F. A. of Mr. Fox's apparatus, as having been the most extensively employed. The observations with this needle commenced at Woolwich, as a base station, on the 7th of July 1842. In the transport in which Lieut. Lefroy made his passage to Canada in July and August, it was employed to give determinations of the Inclination and Force on all days when the weather permitted. The greater part of these determinations belong to a part of the globe which is not now under consideration, and will not therefore be discussed on the present occasion; but a continuation of the series at some stations in Lower Canada, and at several in the United States which Lieut. Lefroy visited on his way to Toronto, for the purpose of connecting the base stations of other observers with his own future base station at Toronto, will be found in Table XII. The deflections obtained with this needle at Toronto on the 26th of October 1842, with the same weights which had been used at Woolwich in July, gave for the ratio of the total force at Toronto 1·3395 to 1 at Woolwich; or 1·838 to 1·372 in terms of the usual arbitrary scale. Two subsequent determinations, one with the same apparatus in 1846, and the other derived from absolute measures of the horizontal Force at Toronto and Woolwich, gave each 1·835 to 1·372; these determinations have been discussed in the introductory remarks, pages 244 to 247, the result of the discussion being that 1·836 has been finally adopted.

On the 28th of October, the needle F. A. being put away in its case, a very powerful bar magnet was inadvertently laid on the top of the case for a few minutes. Observations made on the following day (the 29th), compared with those which had been made on the 26th, showed that the needle had sustained a sensible loss of magnetism by this accident. A new series therefore in the determinations with this needle was commenced on the 29th of October, referring to Toronto as a base station, at which the value of the force is expressed by 1·836 as before. In November 1842, F. A. was employed by Lieut. YOUNGHUSBAND, R.A. at four stations in the states of Ohio and Michigan, and was brought back to Toronto in the same month: the abstract of these observations is given in Table XIII. In the first three months of 1843 the observations were made in high and low temperatures, by which the coefficient in the temperature correction was determined; and repetitions were made on different days in natural temperatures of the angles of deflection with several weights which were afterwards employed in the countries to the north. Towards the end of April Lieut. LEFROY embarked at La Chine in the canoes of the Hudson's Bay Company, and commenced a course of observations, which was continued daily with very few intermissions until his arrival at Athabasca towards the end of September, at the conclusion of the season of navigation. The observations with F. A. were made by Lieut. LEFROY himself until the station of the 11th of May at the Trou Portage; and from thenceforward by Bombardier HENRY, unless where specially noticed in the column of remarks in Tables XIV., XV. and XVI.; towards the end of July the performance of the needle was thought to be somewhat impaired, and in consequence, at York Factory, the terminations of the axles which worked in jewels, as well as the jewels themselves, were carefully examined with a microscope; the front axle was found in admirable order, but the polish of the back axle was not good on one side. The jewels were in good order; the front jewel was scratched on the face and round the edge of the cylindrical bore, probably by the end of the axle in mounting the needle, but the scratches did not appear to enter the bore or affect the bearing points; F. A. was continued in constant use until the end of the season, but its performance was occasionally sluggish and unsatisfactory in comparison with what it had formerly been, and led to its being only occasionally employed in the following year. On the return to Toronto at the close of 1844, the observations were repeated with the weights which had been used in the north; the performance of the needle on that occasion was considered to be a decided improvement on former ones, and the angles of deflection agreed within limits of ordinary error with the angles observed in 1843, before the journey to the north; showing that the magnetism of the needle had sustained no deterioration during the interval. The abstract of the observations with this needle from 1842 to the close of 1844, are given in Tables XIV., XV. and XVI.

Needle F. C. had been kept in reserve at the different stations of the Survey whilst F. A. continued to give satisfactory results. Being examined at York Factory, the polish of the axle was found perfectly good, but the back axle had been injured in shape. A spare axle had been furnished with the apparatus, and appearing perfect both in shape and polish, it was fitted to F. C., and observations were made with this needle at Norway House on the 11th of August 1843, and were repeated at the same spot on the 7th of September 1844. The magnetism of the needle appeared steady, but from some undiscovered cause its performance at some other stations at which it was tried was sluggish and irregular, so that no satisfactory results were obtained with it at them. On the return to Toronto, the angles of deflection were observed with the same weights which had been used at Norway House in August 1843 and September 1844. These give an identical value for the increase of the magnetic force between Toronto and Norway House, to that obtained by the other needle of the apparatus F. A.; the particulars are given in Table XVII.

In Mr. Fox's apparatus the angle of deflection with any particular weight is half the difference of the arcs shown with the weight first on the one hook, and then on the other hook. The experiment is repeated with the face of the circle both east and west, and the angle of deflection entered in the Table is the mean of the angles with the face of the circle east and west.

L. A. and L. B. were the needles on Dr. Lloyd's statical principle fitted to the Gambey's circle; at Toronto, in January and February 1843, the observations were made with them in Table X., by which the coefficient in the temperature correction was determined; and angles of deflection with weights inserted in the hole most distant from the axle were observed for the purpose of supplying a base determination. On arriving at St. Helen's, however, the angles of deflection appeared inconveniently large, and the weights were shifted in each needle into the middle hole, and a new series of relative determinations commenced. The angles of deflection having been observed on the same day at St. Helen's with the weight both in the middle and in the outer hole, the second series become thereby connected with the former; but the advantage of the frequent repetition which had been made at Toronto as a base station was impaired, inasmuch as the connection of the second series commencing at St. Helen's is established by a single observation only in each position of the weights. On arriving at Fort William at the end of May, it was found necessary again to change the weights, because the view of the part of the circle opposite to which the needle rested was interrupted by the cross bar which supports the agate planes. In the case of L. B., the weight was now replaced in the hole in which it had been used at Toronto, and the connection of the subsequent observations with the original base station was thereby fully restored. In the case of L. A., a new weight appears to have been chosen, and as observations were made at Fort William both with the old and the new weight, the two series with this needle,—viz. before and after the change of the weight at Fort William,—have that station common to both. From the time of the embarkation in the Hudson's Bay Company's canoes at La Chine, on the 30th of April, L. A. was in constant and L. B. in occasional use. This continued until the 20th of June at Rat Portage, when the circle was accidentally thrown down, and the axle of L. A., which was mounted at the time for observation, was bent. The injury which the circle had received was repaired a few days afterwards at the Red River settlement; an endeavour was made to straighten the axle of the needle, and with so much success, that observations were occasionally made with it at subsequent stations; the same weight was used as before, but the angles of deflection were of course not comparable with the preceding ones. L. B. was now taken into daily use; and as in this needle the weight was the same as at Toronto and in the same position, the observations continued for some time forward to be directly referable to the base observations at Toronto. On arrival at York Factory the angles of deflection were again found to have become inconveniently large: a new weight was substituted, and continued in use until the 8th of August at Norway House, when the position of the weight was again changed, the angles of deflection in both positions being however observed: Norway House is thus a station common to three of the four series with this needle, and is itself directly connected with Toronto by one of the series. Observations with L. B. were continued to the close of the navigation in 1843, but were not resumed in 1844 with either of the Lloyd's needles.

Under the circumstances which have been narrated, the course which has appeared to be best suited for the deduction of the variations of the magnetic Force resulting from the observations with L. A. and L. B., has been to ascertain, in the first instance, with as much precision as possible, the ratio of the magnetic force at Norway House to that at Toronto, and to regard Norway House as a base station for those series with L. A. and L. B., which are directly connected with it. By this means the only remaining unconnected series with Lloyd's needles is that with L. A. between St. Helen's and Fort William; and this series has been connected with the others, by obtaining in a similar manner the value of the Force at Fort William as a base station from the observations with all the other needles.

For the increase therefore of the total Force between Toronto and Norway House we have the following determinations by three independent methods: viz.—

1. *By* Mr. Fox's *Method and Apparatus.*

Needle F. A.—The first and apparently the best comparison with this needle is furnished by the angles of deflection observed with weights from two to four grains in natural temperatures at Toronto, on different days in January, March and April 1843, before Lieut. Lefroy's departure to join the Hudson's Bay Company's boats, and the angles of deflection observed with the same weights at Norway House on the 13th July following; the observations will be found in Table XIV. From this comparison we have the force at Norway House = 1·0196 to 1 at Toronto.

For a second comparison with this needle we may unite the whole of the deflections observed with the weights at Toronto at different times between October 1842 and December 1844 (Tables XIII., XIV. and XVI.), and the whole of the deflections observed with the same weights at different times at Norway House, viz. on July 13, 1843; August 7, 8, 9, 1843; and September 7, 1844 (Tables XV. and XVI.). From this comparison we obtain the force at Norway House = 1·0171 to 1 at Toronto; and we may consider the mean of these two determinations, or 1·0184, as the result with F.A.

Needle F. C.—By combining the angles of deflection observed with this needle at Norway House, with weights from 1·5 to 3·5 grains, on the 11th of August 1842 after the new axle had been applied to it, and repeated on the 7th of September 1844 with very small variation in the results,—with the angles observed with the same weights and the same axle at Toronto on the 14th and 17th of December 1844,—we obtain the Force at Norway House = 1·0184 to 1 at Toronto; which is precisely the same result as that deduced by needle F. A. The observations will be found in Table XVII.

We may therefore regard 1·0184 as the ratio of the Force at Norway House to unity at Toronto by Mr. Fox's method.

2. *By* Dr. Lloyd's *Method and Needles.*

L. A.—In consequence of the accident which befel this needle on the 20th of June 1843, on the route between Toronto and Norway House, the connection of the series was broken, and we can derive no aid from it for the present purpose.

L. B.—With this needle we have the deflections in natural temperatures at Toronto, in January and February 1843, in Table X., and with the same weight at Norway House on the 12th of July in the same year, in Table XXII. From this comparison we obtain the force at Norway House = 1·0232 to 1 at Toronto. When Lieut. Lefroy visited Norway House in August of the same year, the observations with this weight do not appear to have been repeated; it had been considered expedient to change the weight employed in deflecting the needle at York Factory, and as the angles both with the old and new weights were observed at that station, and as nearly under the same circumstances as possible, we are furnished with the means of computing the equivalent value of $\frac{\cos v}{\sin (v-\theta)}$ for either weight at any other station, where one of the weights only may have been employed. If then we compute this value for the old weight, from the angles with the new one which were observed at Norway House on the 7th, 8th and 11th of August 1843 (Table XXIII.), we obtain a second comparison with the original angles of deflection at Toronto, which gives the force at Norway House = 1·0185. The indirect process by which this last determination is obtained is to a certain degree a diminution of its value. On the other hand, it represents observations repeated on three different days at Norway House, whereas the first determination is from the observations of a single day only. Not feeling confident that either determination is entitled to a decided preference over the other, I have regarded the mean, 1·0208, as the most satisfactory result which I am able to derive from the observations with this needle at Toronto and Norway House; and therefore as the result by Dr. Lloyd's method.

3. *By absolute measures of the Horizontal Force.*

The value of the horizontal force in absolute measure at Norway House is given by Lieut. Lefroy at 2·1742, derived from the experiments with two magnets in July 1843, and with three magnets in September 1844, Table XXXVIII.

The Inclination observed at Norway House in 1843 and 1844 is 81° 09′·8. Hence the total magnetic force at Norway House = 14·15 in absolute measure.

At Toronto we have the horizontal force 3·535 by the experiments with the three survey magnets in January, February and March 1845, Table XXXVIII. The Inclination at this period, taken to the nearest minute from the observations at the observatory, made twice in each week, is 75° 14′. Hence the total magnetic force at Toronto at that period was 13·87. If therefore the total force at Toronto be taken as unity, the ratio at Norway House is $\frac{14\cdot15}{13\cdot87}=1\cdot0205$. It is right to notice that the value of the total force at Norway House would be altered 0·027, and the ratio of the force at Toronto and Norway House ·0019 by a correction of 1′ only in the observed dip; and that the uncertainty which must attach to a determination of the dip made with a single instrument, even under the most favourable circumstances, taking into account both the possibility of constant errors, and the probable observation error, can scarcely be deemed so small as 1′.

Collecting then in one view the results of the three methods, we have the ratio of the total Force at Norway House as follows:—

By Mr. Fox's method . . .	1·0184 to 1 at Toronto.
By Dr. Lloyd's method . . .	1·0208 to 1 at Toronto.
By absolute measure . . .	1·0205 to 1 at Toronto.

As there do not appear sufficient grounds to assign a decided preference to any one of these results over the other two, and as, moreover, they are much more accordant with each other than might reasonably have been expected, we appear to be justified in taking 1·020 as probably a very near approximation to the true ratio of the total magnetic force at Norway House to unity at Toronto. If the Force at Toronto be taken at 1·836 in the arbitrary scale, then the value of the force at Norway House, in terms of the same scale, is 1·873: which has been considered the value whenever Norway House has been used as a base station.

For the ratio of the total Force at Fort William we have the result of the two series of observations with F. A. at that station on the 29th of May 1843, one by Lieut. Lefroy and the other by Bombardier Henry, with the same weights which had been used at Toronto in the early part of the same year (Table XIV.); these give the value of the Force =1·867. We have also the observations with L. B. on the same day (May 29th) at Fort William, included in the same series with the observations of the 12th of July at Norway House (Table XXII.); from these we have the Force at Fort William =1·864. The mean of the two determinations is 1·8655; which has therefore been taken as the value whenever Fort William has been used as a base station.

Tables XVIII. to XXIV. contain the several series with needles L. A. and L. B., arranged according to the base stations to which they respectively refer. The angles of deflection in these tables are always a mean of the angles in four different positions of the needle and circle; *i. e.* with the face of the circle turned towards the east and towards the west, and with the needle reversed on its supports so that each end should rest alternately on the opposite plane.

Since Lieut. LEFROY's return to Canada from the Hudson's Bay territories, GAMBEY's circle has been supplied with a second pair of statical needles on Dr. LLOYD's principle. These needles were used in 1845 by Lieut. YOUNGHUSBAND, R.A., at four stations in Canada, and by Lieut. LEFROY at six stations in Canada and the United States; the observations are contained in Tables XXV. and XXVI.

TABLE XII.—Observations on the Magnetic Force with Fox's Needle F. A., made by Lieut. LEFROY in 1842 between Woolwich and Toronto.

Station.	1842.	Angles of deflection with weights of						Temperature.	Intensity.	Remarks.
		2·0 grs.		2·5 grs.		3·0 grs.				
		°	′	°	′	°	′	°		
Woolwich	July 7.	27	30·0	35	29·1	44	00·9	58·5	1·372	Base station.
Quebec	Sept. 1.	20	20·1	25	45·8	31	34·5	74	1·829	Royal Artillery Barracks.
Three Rivers..	6.	20	23·0	25	40·8	31	31·4	66	1·828	Mr. BELL's Garden.
Sorel	8.	20	30·8	25	57·6	31	36·1	61	1·817	Bank E. of the Roman Catholic Church.
Kingsey	10.	20	35·8	26	00·3	31	47·8	60	1·810	Captain Cox's Garden.
Stanstead	12.	20	38·6	26	06·1	32	06·1	60	1·801	Garden of the Hotel near the Church.
St. Helen's....	16.	20	32·5	25	51·7	31	48·3	59	1·813	100 yards S.S.W. of the Barracks.
New York	26.	21	01·6	26	46·0	32	39·2	71	1·771	Lunatic Asylum, Manhattanville.
Providence....	28.	20	45·8	26	39·1	32	32·2	75	1·783	Steam-boat landing.
Cambridge....	Oct. 3.	20	50·7	26	34·5	32	30·1	63	1·779	Garden of the Observatory.
Philadelphia ..	6.	20	31·1	26	19·7	32	22·2	62	1·795	Girard College.
Baltimore	8.	20	51·6	26	22·2	32	26·5	62	1·784	Washington's Monument N. 42° E., distant 400 yards.
Washington ..	10.	20	54·8	26	38·1	32	41·1	63	1·774	In the grounds west of the Capitol.
Princeton	14.	20	53·0	26	23·1	32	18·0	62	1·785	Field 200 yards east of the College.
Newhaven	18.	21	00·5	26	33·5	32	39·4	67	1·775	In an open space in Grove Street.
West Point....	19.	20	32·8	26	03·6	31	44·5	54	1·809	Professor BARTLETT's Garden.
Albany	21.	20	38·9	26	12·0	32	00·5	55	1·799	Hill between Orange and Patroon Streets.
Toronto	26.	20	12·3	25	34·8	31	19·7	57	1·838	Magnetic Observatory.

Note.—The Force at Toronto having been finally taken at 1·836 (p. 244 to 247), the values given in this Table for the stations in Canada and the United States require to be diminished by ·002, and have accordingly been so diminished in Table XXVII., in which the several determinations with the statical needles are collected in one view.

TABLE XIII.

Observations with Needle F. A., by Lieut. YOUNGHUSBAND, R.A., in November 1842.

Station.	1842.	Angles of deflection with weights of 1·5 gr.	2·0 grs.	2·5 grs.	Temperature.	Intensity.	Remarks.
Toronto	Oct. 29.	21° 14′·6	27° 00′·5	33° 11′·6	53°	1·836	Base station.
	Dec. 30.	21 18·5	27 08·0	33 08·2	43		
Cleveland	Nov. 3.	21 34·4	not observed.	33 58·3	56	1·807	Inland from the Wharf.
Detroit	4.	21 23·4	27 12·3	33 25·8	47	1·826	40 yards from the Wharf.
S.Manitou Island	7.	21 15·5	26 55·8	32 55·0	54	1·846	40 yards from the Wharf.
Chicago	15.	21 26·7	27 14·1	33 26·4	47	1·823	Dr. ELDRIDGE's Garden.
	16.	21 29·7	27 12·7	33 25·1	47		

TABLE XIV.

Observations on the Magnetic Force with Fox's Needle F. A., between Toronto and Norway House, from January 1844 to July 1844.

Station.	1843.	Angles of deflection with weights of 2·0 grs.	2·5 grs.	3·0 grs.	3·5 grs.	4·0 grs.	Thermometer.	Intensity. Toronto = 1·836.	Remarks.
Toronto	Jan. 4.	21° 09′·9	26° 52′·2	33° 05′·0	° ′	° ′	26		
	4.	21 08·8	26 45·9	33 02·8	......	......	27		
	12.	21 12·3	27 04·2	33 21·6	......	46 45·4	36		
	12.	21 21·8	27 00·3	33 15·2	......	46 42·1	35		
	12.	......	......	33 14·8	......	......	34		
	14.	21 09·4	26 53·1	......	......	......	30		
	14.	21 12·6	26 58·8	......	......	......	27		
	16.	21 10·0	27 08·4	33 07·4	......	46 41·4	34		
	March 8.	21 14·7	27 16·6	32 59·7	39 34·4	46 42·5	60		
	8.	......	27 16·1	33 06·1	......	46 42·1	59		
	9.	21 17·6	27 06·1	33 05·0	......	46 42·7	60		
	April 6.	......	26 57·6	33 06·0	39 22·0	46 57·9	46		
	7.	......	27 08·3	33 12·0	39 24·5	46 53·0	59		
	Mean..	21 13·0	27 02·3	33 08·7	39 27·0	46 45·9	46	1·836	Base station.
St. Helen's............	April 25.	......	27 21·9	33 21·4	39 58·9	......	54	1·821	
Isle d'Urval	30.	......	27 27·2	33 37·0	40 30·9	47 55·0	47	1·805	
La Combes	May 2.	......	26 44·2	33 23·2	39 43·5	47 05·4	48	1·833	
Pte aux Chênes	3.	......	27 47·2	33 47·7	40 43·0	47 54·8	56	1·800	
Foxes Point	4.	......	27 10·3	32 56·0	39 35·2	46 42·2	50	1·837	
Chat Falls	6.	......	26 49·1	33 03·8	39 15·2	46 33·6	53	1·846	
Grand Calumet	7.	......	27 24·9	33 29·6	40 01·4	47 05·1	74	1·826	
Fort Coulonge	8.	......	26 47·2	33 01·8	39 31·0	47 10·5	55	1·841	
Pte Baptême	9.	......	27 22·2	33 24·1	40 00·2	47 13·4	57	1·822	
Deux Joachims Portage..	10.	......	27 22·0	33 31·8	40 02·7	46 56·9	74	1·827	
Trou Portage..........	11.	......	27 07·5	33 12·6	39 36·7	46 48·3	80	1·842	
Little River	12.	21 10·7	27 10·1	32 47·6	39 49·6	46 23·2	78	1·836	
L. du Grand Vase........	13.	......	26 44·0	33 02·9	39 53·7	47 08·6	72	1·843	
Ricolet Falls	15.	......	26 21·0	32 55·8	38 31·4	45 44·2	61	1·871	
Pte au Croix	16.	......	26 14·6	32 52·7	39 40·6	46 35·4	49	1·852	

Table XIV. (Continued.)

Station.	1843.	Angles of deflection with weights of					Thermometer.	Intensity.	Remarks.
		2·0 grs.	2·5 grs.	3·0 grs.	3·5 grs.	4·0 grs.		Toronto = 1·836.	
Lake Huron	May 17.	......	27° 10′·3	33° 13′·3	39° 17′·2	46° 51′·6	59°	1·838	
Snake Island	18.	......	27 39·5	33 13·0	39 58·2	46 33·7	68	1·829	
Tessalon Point	19.	......	26 49·8	32 22·7	39 38·2	46 12·3	69	1·860	
Pointe aux Pins........	20.	......	26 37·2	32 09·3	39 29·2	46 16·4	70	1·867	
P^te^ au Crêpe	21.	......	26 00·4	31 30·6	38 04·8	44 36·7	73	1·910	
Fort Michipicoton......	23.	......	26 29·5	32 56·9	38 57·8	46 37·1	40	1·851	
Otter Island	24.	......	27 32·5	34 06·0	40 43·8	49 08·7	52	1·790	
Pic Fort..............	25.	......	27 14·5	33 06·4	38 52·5	47 22·9	66	1·841	
Terreplatte	27.	......	27 06·4	32 28·4	39 21·6	45 42·5	45	1·853	
Pointe Tonnerre	28.	......	25 56·5	31 58·3	38 20·8	46 19·9	58	1·890	
Fort William..........	29.	......	26 40·4	32 22·8	38 51·8	46 05·0	73	1·867	
Fort William..........	29.	......	26 33·3	32 37·8	39 11·0	45 48·3	63		L.
Portage Ecarté	June 2.	......	26 38·6	32 40·8	39 26·8	46 14·9	48	1·852	
Chien Portage	3.	......	26 31·9	32 27·7	38 45·1	45 43·9	47	1·868	
Prairie Portage........	5.	......	26 38·2	32 43·1	39 03·6	46 09·1	56	1·859	
Savannah Portage......	6.	......	26 42·6	32 39·8	38 51·2	45 52·9	65	1·866	
French Portage........	7.	......	26 40·3	32 42·3	39 00·5	46 04·5	60	1·861	
Portage des deux Rivières	8.	......	26 32·0	32 32·1	39 04·0	46 04·2	57	1·864	
Lac à la Crosse........	10.	......	26 39·0	32 39·0	39 16·6	46 11·1	61	1·859	
2nd Portage from ditto..	11.	......	26 53·4	32 53·9	39 07·7	46 16·3	69	1·855	L.
Sturgeon Lake	12.	......	26 34·8	32 31·8	39 10·1	46 04·8	68	1·866	
Lac la Pluie	13.	......	26 32·5	32 49·8	39 02·5	46 02·8	55	1·861	
Fort Francis	14.	......	26 50·8	32 50·3	39 24·8	46 05·9	62	1·853	
Rainy River	16.	......	26 16·3	32 03·0	38 22·0	45 26·3	64	1·890	
Lake of the Woods	17.	......	26 36·6	32 36·8	38 59·6	45 52·2	67	1·871	
Lake of the Woods	18.	......	26 44·4	32 48·0	38 58·8	46 20·0	82	1·864	
Rat Portage	20.	......	26 48·2	32 47·2	39 18·5	46 07·6	67	1·858	
Winnipeg River........	22.	......	26 23·9	32 30·7	38 50·4	45 38·3	71	1·877	L.
Slave Portage	23.	......	26 34·7	32 44·3	39 21·3	46 16·3	87	1·867	
Fort Alexander........	25.	......	26 50·5	32 47·4	39 35·3	46 05·7	78	1·857	
Lake Winnipeg	26.	......	26 38·6	32 37·0	39 05·5	46 11·3	80	1·867	
Upper Fort Garry......	29.	......	26 39·4	32 38·9	39 17·5	46 12·2	72	1·861	L.
Upper Fort Garry......	July 3.	......	26 51·2	32 40·8	39 13·7	46 07·7	84		
Mouth of the Red River.	4.	......	26 44·6	32 42·9	39 07·0	46 06·5	66	1·861	
Lake Winnipeg........	5.	......	26 42·8	32 42·2	39 07·2	46 20·9	66	1·859	
Lake Winnipeg........	6.	......	25 53·2	31 44·2	37 56·4	44 49·8	61	1·909	
Lake Winnipeg	7.	......	26 19·9	31 46·1	38 02·5	44 46·0	69	1·904	
Lake Winnipeg	8.	......	26 15·4	32 20·4	38 16·6	46 25·0	66	1·880	
Lake Winnipeg	10.	......	26 08·9	33 04·3	38 47·3	46 28·9	65	1·862	
Lake Winnipeg	10.	......	26 45·9	33 04·2	39 28·4	45 52·5	71		
Norway House	13.	......	26 41·0	32 14·4	39 08·3	45 36·9	70	1·872	

Commencing with the 12th of May at Little River, these observations were made by Bombardier Henry, R.A., except where L. is inserted in the column of remarks.

TABLE XV.

Observations on the Magnetic Force with Fox's Needle F. A., between Norway House and Athabasca, from July 1843 to October 1843; observer, Bombardier HENRY, R.A.

Station.	1843.	Angles of deflection with weights of					Thermometer.	Intensity.	Remarks.
		2·0 grs.	2·5 grs.	3·0 grs.	3·5 grs.	4·0 grs.		Toronto =1·836.	
Norway House	July 13.	° ′	26° 41′·0	32° 14′·4	39° 08′·3	45° 36′·9	70°		
	Aug. 7.	20 45·3	26 41·9	32 45·9	39 08·9	45 57·1	78		
	8.	20 59·8	26 39·3	33 17·6	39 20·0	45 56·7	82		
	9.	20 35·7	26 53·2	32 56·8	39 24·1	46 31·1	85		
	Mean	20 45·6	26 44·3	32 48·7	39 15·3	46 00·5	79	1·873	Base.
Long Portage........	July 20.	......	26 52·4	32 19·4	38 48·1	45 40·4	64	1·880	
Long Portage..........	Aug. 2.	......	26 50·0	32 22·9	39 41·9	45 45·3	71		
White Earth Portage ..	July 21.	......	26 47·0	32 00·5	39 34·2	46 58·7	81	1·869	
White Earth Portage ..	31.	......	27 11·7	32 23·1	38 46·2	46 29·2	59		
Shamatawa............	22.	......	26 43·9	33 35·2	39 56·8	47 09·6	63	1·862	
Shamatawa	28.	......	26 32·5	32 57·5	38 19·9	45 57·7	70		
York Factory..........	24.	......	26 57·3	32 30·3	39 05·0	46 59·1	70	1·857	
York Factory..........	25.	......	27 13·0	33 16·5	39 44·1	45 55·0	56		
Hill River	Aug. 1.	......	26 42·0	32 31·6	39 06·1	45 57·0	66	1·875	
Oxford House	3.	......	26 56·6	32 01·3	38 35·4	45 11·3	66	1·889	
Windy Lake	4.	......	26 20·4	32 30·8	39 17·8	46 07·5	76	1·870	
Whitefall Portage	5.	......	26 41·4	32 32·2	39 19·3	45 45·3	82	1·879	
Hairy Lake	6.	21 00·6	27 01·9	32 54·1	39 18·9	46 09·9	73	1·861	
Lake Winnipeg	14.	......	26 49·7	32 51·2	38 46·0	46 05·9	70	1·872	
Grand Rapid..........	15.	......	26 54·9	32 29·6	38 47·9	46 07·6	67	1·874	
Cross Lake............	16.	......	26 38·4	32 33·8	38 51·6	46 20·7	68	1·875	
Cedar Lake	18.	......	26 51·0	32 22·6	39 29·0	46 15·0	74	1·871	
Cumberland House	23.	......	26 56·9	32 35·4	39 24·4	46 12·7	62	1·865	
Cumberland House	24.	......	26 45·4	32 33·6	39 22·4	46 12·8	55		
Beaver Lake	26.	......	26 42·3	32 50·4	38 37·7	46 41·1	64	1·869	
Portage des Epinettes ..	27.	......	26 33·3	32 35·0	39 02·4	46 18·8	56	1·871	
Frog Portage..........	29.	......	26 28·6	33 17·1	39 23·4	46 49·4	58	1·857	
Little Rock Portage	31.	......	24 48·0	30 28·7	35 54·1	43 01·4	64	1·995	
Great Devil's Portage ..	Sept. 1.	......	26 43·2	32 39·6	39 11·9	46 57·0	72	1·875	
Great Devil's Portage ..	1.	......	26 00·3	32 42·1	38 40·0	46 32·6	67		
Pine Portage..........	3.	......	26 00·3	32 42·1	38 40·0	46 32·6	67	1·884	
Snake Rapid	4.	......	26 22·0	32 43·3	38 40·4	46 40·0	54	1·874	
Portage Sonnante	7.	......	26 39·4	33 01·2	39 12·1	46 50·1	52	1·858	
Isle à la Crosse	9.	......	26 38·2	33 12·2	38 56·8	47 20·7	64	1·857	
Isle à la Crosse	9.	......	26 42·5	33 18·2	38 57·0	47 18·6	70		
Buffaloe Lake..........	13.	......	26 58·5	33 16·0	39 05·0	......	54	1·854	
River de la Loche......	14.	......	27 21·7	34 04·8	40 09·0	47 20·9	70	1·826	
Portage de la Loche....	16.	......	26 54·4	33 11·8	40 02·8	48 14·8	60	1·835	
Clearwater River	19.	......	26 56·6	33 13·6	39 12·9	46 30·3	44	1·850	
Pierre au Calumet......	20.	......	25 20·3	31 33·6	37 14·1	44 46·6	55	1·938	
Pointe Brulée..........	21.	......	27 16·5	23 11·5	38 32·8	46 35·8	43	1·852	
Athabasca	25.	......	27 06·0	33 43·4	39 53·8	47 39·1	44	1·828	
Athabasca	25.	......	27 03·3	33 28·0	39 58·9	47 52·3	44		
Athabasca	Oct. 9.	......	26 48·7	33 45·7	39 55·5	47 34·5	36		

TABLE XVI.

Observations on the Magnetic Force with Fox's Needle F. A., between Athabasca and Toronto, from July 12th, 1844, to December 17th, 1844: Observer, Bombardier HENRY, R.A.

Station.	1844.	Angles of deflection with weights of					Temp.	Intensity.
		2·5 grs.	3·0 grs.	3·5 grs.	4·0 grs.	4·5 grs.		Toronto = 1·836.
Toronto	Dec. 14.	26° 52′·6	33° 18′·4	39° 16′·6	46° 39′·2	54° 25′·6	41°	
	Dec. 17.	26 40·8	33 02·4	39 13·7	46 42·1	54 33·1	32	
	Mean..	26 46·7	33 10·4	39 15·2	46 45·5	54 29·3	36·5	1·836
Fort Vermilion....	July 12.	27 20·1	33 51·3	40 07·0	47 44·8	56 10·7	68	1·811
Fort Dunvegan ..	23.	27 06·6	33 47·8	40 15·5	47 57·1	56 03·4	54	1·809
Fort Edmonton ..	Aug. 17.	27 19·7	33 47·2	40 03·0	47 21·5	55 26·0	38	1·809
Cumberland House	30.	26 37·0	32 56·8	38 59·0	46 24·9	54 06·2	61	1·853
Norway House....	Sept. 7.	26 22·9	32 54·3	38 53·6	46 29·2	54 09·6	60	1·858

TABLE XVII.

Observations on the Magnetic Force with Fox's Needle F. C., between Norway House in August 1843, and Toronto in December 1844.

Station.	1844.	Angles of deflection with weights of					Temp.	Intensity.	
		1·5 gr.	2·0 grs.	2·5 grs.	3·0 grs.	3·5 grs.		Toronto = 1·836.	
Toronto	Dec. 14.	19° 43′·6	27° 23′·0	34° 48′·5	43° 42′·4	53° 56·8	40°		
	Dec. 17.	19 47·1	27 17·7	34 47·5	43 42·5	53 55·0	32		
	Mean..	19 45·3	27 20·4	34 48·0	43 42·4	53 55·9	36	1·836	Base station.
Norway House....	1843. Aug. 11.	19 32·2	26 54·5	34 12·0	42 39·3	52 33·0	56		
Norway House....	1844. Sept. 7.	19 33·8	26 50·3	34 20·0	43 09·4	52 11·3	56		
	Means..	19 33·0	26 52·4	34 16·0	42 54·3	52 22·1	56	1·870	

TABLE XVIII.—Observations on the Magnetic Force with LLOYD's Needle L. A., from St. Helen's (in Canada) to Fort William, in April and May 1843.

Station.	1843.	Angles of deflection.	Temp.	Inclination.	Intensity. Toronto = 1·836.	Remarks.
Fort William	May 29.	° ′ − 9 37·7	° 70	° ′		
		− 9 41·1	56			
	Mean..	− 9 39·4	63	78 10	1·8655	Base station.
St. Helen's	April 25.	−15 06·1	60	77 05·5	1·826	
Isle d'Urval............	30.	−16 26·9	45	77 21·1	1·817	
La Combes............	May 2.	−14 35·6	49	76 50·6	1·829	
P^te aux Chênes	3.	−17 10·0	49	76 55·4	1·810	
Point Aylmer..........	5.	−15 05·8	52	76 41·0	1·825	
Fort Coulange	8.	−12 13·8	53	77 29·7	1·847	
Deux Joachims Portage..	10.	−14 04·9	70	77 03·8	1·834	
Trou Portage..........	11.	−13 24·5	87	77 24·4	1·840	
Little River	12.	−13 12·6	69	77 28·5	1·841	
L. du Grand Vase	13.	−12 05·2	86	77 21·7	1·849	
Lake Nipissing	14.	−13 48·0	64	77 09·5	1·836	
Ricolet Falls	15.	− 9 15·7	60	76 45·4	1·870	
P^te au Croix	16·	−11 41·0	50	76 31·3	1·852	
Lake Huron	17·	−12 57·3	51	77 05·6	1·843	
Snake Island	18·	−13 41·2	68	77 05·5	1·837	
Tessalon Point	19·	−12 42·3	52	76 59·3	1·844	
Pointe aux Pins	20·	−11 02·4	70	77 13·4	1·858	
Pointe au Crèpe........	21·	−12 47·4	63	77 11·5	1·844	
Michipicoton	23·	−10 26·4	46	78 06·3	1·859	
Otter Island	24·	−18 20·8	51	79 43·6	1·812	
Pic Fort..............	25·	−11 46·6	58	78 45·8	1·851	
Terreplatte............	27·	−11 02·6	48	78 53·6	1·855	
Pointe Tonnerre	28·	−10 02·7	55	78 23·2	1·862	

TABLE XIX.—Observations on the Magnetic Force with LLOYD's Needle L. A., between Fort William and Rat Portage (where the needle met with an accident) in the months of May and June 1843.

Station.	1843.	Angles of deflection.	Temperature.	Inclination.	Intensity. Toronto = 1·836.	Remarks.
Fort William	May 29.	° ′ −17 09·6	° 53	° ′		
	29.	−17 09·9	53			
	Mean ..	−17 09·75	53	78 10	1·8655	Base station.
Portage Ecarté	June 2.	−18 38·2	52	77 13·5	1·852	
Chien Portage	3.	−17 41·4	47	78 26·8	1·863	
Prairie Portage	5.	−18 34·4	53	78 26·2	1·857	
Savannah Portage	6.	−16 52·4	60	78 21·8	1·869	
French Portage	8.	−18 01·6	60	78 20·4	1·860	
Portage des deux Rivières..	9.	−17 41·8	58	77 49·4	1·861	
Lac à la Crosse	10.	−17 41·9	58	77 51·0	1·861	
2^d Portage from the Lake ..	11.	−18 27·5	72	77 40·1	1·855	
Sturgeon Lake	12.	−18 08·2	66	77 44·8	1·857	
Lac la Pluie	13.	−18 12·5	60	77 47·9	1·857	
Fort Francis	14.	−17 48·3	63	77 28·0	1·859	
Rainy River	16.	−11 20·6	66	77 57·4	1·906	
Lake of the Woods	17.	−17 27·2	65	78 03·7	1·863	
Lake of the Woods	18.	−19 51·6	79	78 16·7	1·847	

Table XX.

Observations on the Magnetic Force with Lloyd's Needle L. A. (after the axle had been straightened), between Upper Fort Garry on the 3rd of July 1843, and Lake Winnipeg on the 14th of August 1843.

Station.	1843.	Angles of deflection.	Temperature.	Inclination.	Intensity.	Remarks.
					Toronto = 1·836.	
Norway House	July 12.	− 9° 12′·8	68°	° ′		
	13.	− 9 31·9	76			
	Aug. 8.	−11 17·5	80			
	9.	−11 49·4	84			
	11.	−10 45·4	56			
	Mean ..	−10 31·4	73	81 09·8	1·873	Base station.
Upper Fort Garry	July 3.	−12 45·6	78	78 17·8	1·857	
Lake Winnipeg	10.	−11 36·0	69	80 05·5	1·866	
Long Portage........	20.	− 9 18·0	87	82 13·9	1·880	
Long Portage........	Aug. 2.	− 9 13·0	71			
York Factory........	July 24.	−18 46·7	80	83 47·0	1·848	
York Factory........	25.	−18 07·7	73			
Oxford House	Aug. 3.	11 48·0	60	82 38·8	1·869	
Windy Lake	4.	11 19·0	71	81 57·0	1·870	
Whitefall Portage	5.	13 47·0	79	81 47·9	1·858	
Old Norway House ..	12.	10 35·0	65	80 45·4	1·872	
Lake Winnipeg	14.	13 53·0	64	80 16·8	1·853	

Table XXI.

Observations on the Magnetic Force with Lloyd's Needle L. B., between St. Helen's in Canada on the 25th of April 1843, and Fort William on the 29th of May 1843.

Station.	1843.	Angles of deflection.	Temperature.	Inclination.	Intensity.	Remarks.
					Toronto = 1·836.	
Fort William	May 29.	− 3° 25′·9	80°	78° 10′	1·8655	Base station.
St. Helen's..........	April 25.	−11 00·7	60	77 05·5	1·812	
Isle d'Urval..........	30.	−13 15·2	45	77 21·1	1·796	
Foxes Point	May 4.	− 9 05·0	51	76 35·3	1·827	
Chat Falls	6.	− 8 34·0	50	75 16·1	1·835	
Pointe aux Pins......	20.	− 4 28·6	70	77 13·4	1·861	

TABLE XXII.

Observations on the Magnetic Force with LLOYD's Needle L. B., between Williamsburg in Canada on the 20th of April 1843, and York Factory on the 25th of July 1843.

Station.	1843.	Angles of deflection.	Temperature.	Inclination.	Intensity.	Remarks.
					Toronto = 1·836.	
Norway House	July 12.	−39° 16′·0	70°	81° 09′·8	1·873	Base station.
Williamsburg	April 20.	−34 23·0	55	76 30·0	1·841	
St. Helen's	25.	−36 06·7	52	77 05·0	1·831	
Fort William	May 29.	−34 08·1	55	78 10·0	1·864	
Fort William	29.	−34 03·5	56			
Fort Francis	June 14.	−35 18·2	57	77 28·0	1·846	
Rainy River	16.	−31 08·4	68	77 57·4	1·890	
Upper Fort Garry	July 3.	−34 18·5	78	78 17·8	1·867	
Mouth of the Red River	4.	−34 37·5	64	78 32·6	1·866	
Lake Winnipeg	5.	−35 50·3	70	79 11·8	1·866	
Lake Winnipeg	6.	−30 11·1	59	79 38·0	1·915	
Lake Winnipeg	7.	−31 26·5	67	79 28·3	1·904	
Lake Winnipeg	10.	−37 10·1	66	80 05·5	1·869	
Long Portage	20.	−41 15·7	87	82 13·9	1·881	
White Earth Portage ..	21.	−47 17·0	84	83 03·0	1·857	
Shamatawa	23.	−48 22·0	64	83 26·0	1·863	
York Factory	24.	−50 16·6	85	83 47·0	1·853	
York Factory	25.	−50 44·8	47			

TABLE XXIII.

Observations on the Magnetic Force with LLOYD's Needle L. B., between York Factory on the 26th of July 1843, and Norway House on the 11th of August 1843.

Station.	1843.	Angles of deflection.	Temperature.	Inclination.	Intensity.	Remarks.
					Toronto = 1·836.	
Norway House	Aug. 7.	+13° 39′·0	77°	° ′		
	8.	+12 39·0	81			
	11.	+14 45·0	58			
	Mean ..	+13 41·0	72	81 09·8	1·873	Base station.
York Factory	July 26.	+19 00·2	75	83 47·0	1·861	
York Factory	26.	+18 55·9	74			
Shamatawa	28.	+17 58·0	65	83 36·0	1·858	
White Earth Portage ..	31.	+15 20·0	58	83 03·0	1·855	
Hill River	Aug. 1.	+17 41·0	65	82 55·0	1·867	
Long Portage	2.	+16 21·0	80	82 13·9	1·872	
Oxford House	3.	+18 16·8	68	82 38·8	1·874	
Whitefall Portage	5.	+14 31·8	78	81 47·9	1·870	
Hairy Lake	6.	+11 12·2	75	81 20·9	1·857	

TABLE XXIV.

Observations on the Magnetic Force with LLOYD's Needle L. B., between Norway House on the 11th of August 1843, and Athabasca on the 20th of October 1843.

Station.	1843.	Angles of deflection.	Temperature.	Inclination.	Intensity. Toronto = 1·836.	Remarks.
		° ′	°	° ′		
Norway House	Aug. 11.	−26 12·0	68			
		−25 17·0	58			
	Mean ..	−25 44·5	63	81 09·8	1·873	Base station.
Old Norway House ..	Aug. 12.	−24 28·0	66	80 45·4	1·877	
Lake Winnipeg	14.	−26 26·0	68	80 16·8	1·860	
Grand Rapid	15.	−24 02·0	60	80 21·5	1·876	
Cross Lake..........	16.	−23 59·0	58	80 28·2	1·877	
Cumberland House ..	21.	−25 24·0	55	80 30	1·868	
Cumberland House ..	21.	−25 03·0	55			
Isle à la Crosse	Sept. 9.	−28 18·0	55	80 09·8	1·845	
Isle à la Crosse	9.	−28 20·0	51			
Athabasca	Oct. 20.	−29 33·0	50	81 37·7	1·849	
Athabasca	20.	−30 57·0	50			
Athabasca	20.	−30 41·0	37			
Athabasca	20.	−30 07·0	32			

TABLE XXV.

Observations on the Magnetic Force at Stations in Canada with LLOYD's Needles L. C. and L. D., in June and July 1845, by Lieut. YOUNGHUSBAND, R.A.

Station.	1845.	Needles.	Mean angle of deflection.	Thermometer.	Inclination.	Intensity. Toronto = 1·836.	Remarks.
			° ′	°	° ′		
Toronto	June 3.	C.	−17 28·2	62			Base station.
	3.	C.	−17 38·6	68			
	4.	C.	−17 34·8	64			
	4.	C.	−17 32·7	69			
	5.	C.	−17 28·4	61			
	July 7.	C.	−17 35·0	75			
	7.	C.	−17 32·3	73			
	Mean..	C.	−17 32·9	67	75 13·0	1·836	
	June 3.	D.	−13 50·4	64			
	3.	D.	−13 58·9	67			
	4.	D.	−13 38·9	66			
	4.	D.	−13 34·7	68			
	5.	D.	−13 28·5	63			
	July 7.	D.	−13 44·9	76			
	7.	D.	−13 35·2	72			
	Mean..	D.	−13 41·8	68	75 13·0	1·836	
Brockville ..	June 13.	C.	−20 57·1	72	76 18·9	1 812	Garden at Rockfort.
	13.	D.	−16 52·1	83			
Cornwall ..	16.	C.	−19 36·6	66	76 16·4	1·822	Orchard behind Chesleys.
	16.	D.	−15 17·5	66			
Montreal....	18.	C.	−24 05·5	70	77 08·6	1·788	Garden on the mountain.
	18.	D.	−20 23·1	71			
Quebec	23.	C.	−22 39·6	70	77 08·8	1·801	Near WOLFE's monument.
	23.	D.	−18 29·9	72			

Corrections have been made for the variations of temperature; the coefficient q in these needles is ·000052 for L. C. and ·000058 for L. D.

TABLE XXVI.

Observations on the Magnetic Force at Stations in Canada, with LLOYD's Needles L. C. and L. D., in October and November 1845, by Lieut. LEFROY, R.A.

Station.	1845.	Needles.	Mean angle of deflection.	Thermometer.	Inclination.	Intensity. Toronto = 1·836.	Remarks.
			° ′	°	° ′		
Toronto	Oct. 17.	C.	−17 22·7	49			Base station.
	17.	C.	−17 22·8	50			
	Nov. 3.	C.	−17 41·9	47			
	3.	C.	−17 28·2	48			
	3.	C.	−17 40·8	50			
	Mean..	C.	−17 31·3	49	75 14·3	1·836	
	Oct. 17.	D.	−14 17·6	49			
	17.	D.	−14 24·9	50			
	Nov. 3.	D.	−14 15·1	55			
	3.	D.	−14 18·6	49			
	Mean..	D.	−14 19·0	50	75 14·3	1·836	
Niagara	Oct. 18.	C.	−19 36·7	55	74 46·8	1·822	In a field near the Falls.
	18.	D.	−16 28·8	59			
Buffaloe	20.	C.	−20 19·0	44	74 37·0	1·814	1½ mile distant from the Lake.
	20.	D.	−17 18·9	44			
Amherstburg.	22.	C.	−19 09·1	54	73 30·0	1·822	Garden of the Hon. J. GORDON.
	22.	D.	−16 25·3	49			
Detroit	23.	C.	−20 23·9	54	73 38·8	1·814	Corner of Lafayette and Orleans Streets.
	23.	D.	−16 53·2	55			
Port Sarnia ..	25.	C.	−18 34·2	55	74 15·8	1·825	Garden near the Ferry.
	27.	C.	−18 52·5	68			
	25.	D.	−15 52·6	57			
	27.	D.	−15 44·8	68			
Goderich ..	28.	C.	−18 36·5	69	75 48·0	1·828	Garden at the foot of the Hill.
	29.	C.	−18 38·7	58			
	28.	D.	−15 30·0	75			
	29.	D.	−15 14·6	58			

Corrections have been made for the variations of temperature.

Table XXVII. contains the several determinations with the statical needles of LLOYD and FOX collected in one view, and exhibits a mean of the several statical determinations at each station.

TABLE XXVII.

Results of the Observations on the Magnetic Force with the Statical Needles in Canada and the Hudson's Bay Territories in 1842, 1843, 1844 and 1845.

Station.	Lat.	Long.	L. A.	L. B.	F. A.	Mean.	Remarks.
1842.	° ′	° ′					
Quebec	46 49	288 44	....	....	1·827	1·827	
Three Rivers	46 19	287 24	....	....	1·826	1·826	
Sorel	46 02	287 00	....	....	1·815	1·815	
Kingsey	45 48	287 41	....	....	1·808	1·808	
Stanstead	45 02	287 50	....	....	1·799	1·799	
St. Helen's	45 31	286 25	....	....	1·811	1·811	
New York	40 49	285 57	....	....	1·769	1·769	
Providence	41 50	288 35	....	....	1·781	1·781	
Cambridge	42 22	288 52	....	....	1·777	1·777	
Philadelphia	39 58	284 50	....	....	1·793	1·793	
Baltimore	39 17	283 23	....	....	1·782	1·782	
Washington	38 53	282 59	....	....	1·772	1·772	
Princeton	40 22	285 20	....	....	1·783	1·783	
Newhaven	41 18	287 02	....	....	1·773	1·773	
West Point	41 24	285 59	....	....	1·807	1·807	
Albany	42 39	286 15	....	....	1·797	1·797	
Cleveland	41 30	278 18	....	....	1·807	1·807	
Detroit	42 24	277 00	....	....	1·826	1·826	
South Manitou Island	45 05	274 22	....	....	1·846	1·846	
Chicago	41 53	272 16	....	....	1·823	1·823	
1843.							
Toronto	43 39	280 39	1·836	1·836	1·836	1·836	
St. Helen's	45 31	286 25	1·826	1·821	1·821	1·823	
Isle d'Urval	45 24	286 14	1·817	1·796	1·805	1·806	
La Combes	45 32	285 51	1·829	....	1·833	1·831	
Pointe aux Chênes	45 37	285 05	1·810	....	1·800	1·805	
Foxes Point	45 32	284 26	....	1·827	1·837	1·832	
Point Aylmer	45 15	284 02	1·825	....	....	1·825	
Chat Falls	45 26	283 28	....	1·835	1·846	1·840	
Grand Calumet	45 45	283 20	....	....	1·826	1·826	
Fort Coulonge	45 56	282 56	1·847	....	1·841	1·844	
Pointe Baptême	46 06	282 34	....	....	1·822	1·822	
Deux Joachim's Portage	46 12	281 41	1·834	....	1·827	1·830	
Trou Portage	46 15	281 27	1·840	....	1·842	1·841	
Little River	46 18	281 17	1·841	....	1·836	1·838	
Lac du Grand Vase	46 18	280 34	1·849	....	1·843	1·846	
Lake Nipissing	46 14	280 01	1·836	....	....	1·836	
Ricolet Falls	45 57	278 59	1·870	....	1·871	1·870	
Pointe au Croix	45 55	278 42	1·852	....	1·852	1·852	
Lake Huron	46 00	278 10	1·843	....	1·838	1·840	
Snake Island	46 10	277 10	1·837	....	1·829	1·833	
Tessalon Point	46 16	276 29	1·844	....	1·860	1·852	
Pointe aux Pins	46 29	275 19	1·858	1·861	1·867	1·862	
Pointe au Crêpe	46 58	275 02	1·844	....	1·910	1·877	
Fort Michipicoton	47 56	274 55	1·859	....	1·851	1·855	
Otter Island	48 07	273 45	1·812	....	1·790	1·801	
Pic Fort	48 38	273 31	1·851	....	1·841	1·846	
Terreplatte	48 49	272 15	1·855	....	1·853	1·854	
Pointe Tonnere	48 19	270 58	1·862	....	1·890	1·876	
Fort William	48 24	270 38	....	1·864	1·867	1·8655	
Portage Ecarté	48 25	270 15	1·852	....	1·852	1·852	
Chien Portage	48 39	270 26	1·863	....	1·868	1·865	
Prairie Portage	48 57	269 59	1·857	....	1·859	1·858	
Savannah Portage	48 53	269 57	1·869	....	1·866	1·867	
French Portage	48 35	268 53	1·860	....	1·861	1·860	
Portage des deux Rivières	48 35	268 33	1·861	....	1·864	1·862	
L. à la Crosse	48 24	267 50	1·861	....	1·859	1·860	
2nd Portage from ditto	48 15	267 36	1·855	....	1·855	1·855	
Sturgeon Lake	48 28	267 27	1·857	....	1·866	1·861	
Lac la Pluie	48 32	267 04	1·857	....	1·861	1·859	
Fort Frances	48 37	266 31	1·859	1·846	1·853	1·853	
Rainy River	48 48	265 29	1·906	1·890	1·890	1·895	

TABLE XXVII. (Continued.)

Station.	Lat.	Long.	L. A.	L. B.	F. A.	Mean.	Remarks.
1843.	° ′	° ′					
Lake of the Woods	49 19	265 18	1·863	....	1·871	1·867	
Lake of the Woods	49 28	265 20	1·847	....	1·864	1·856	
Rat Portage	49 46	265 21	....	....	1·858	1·858	
Winnipeg River	50 10	264 50	....	....	1·877	1·877	
Slave Portage	50 11	264 23	....	....	1·867	1·867	
Fort Alexander	50 37	263 39	....	....	1·857	1·857	
Lake Winnipeg	50 27	263 22	....	....	1·867	1·867	
Upper Fort Garry	49 53	262 57	1·857	1·867	1·861	1·862	
Mouth of the Red River	50 19	263 19	....	1·866	1·861	1·863	
Lake Winnipeg	51 04	263 15	....	1·866	1·859	1·862	
Lake Winnipeg	51 38	263 12	....	1·915	1·909	1·912	
Lake Winnipeg	51 45	263 07	....	1·904	1·904	1·904	
Lake Winnipeg	52 23	262 51	....	....	1·880	1·880	
Lake Winnipeg	52 29	262 47	1·866	1·869	1·862	1·865	
Norway House	53 59	261 53	1·873	....	1·873	1·873	
Long Portage	55 15	265 35	1·880	1·877	1·880	1·879	
White Earth Portage	55 26	265 57	....	1·855 1·857 } 1·856	1·869	1·862	
Shamatawa	56 21	267 04	....	1·863 1·858 } 1·860	1·862	1·861	
York Factory	57 00	267 34	1·848	1·853 1·861 } 1·857	1·857	1·855	
Hill River	55 22	266 00	....	1·867	1·875	1·871	
Oxford House	54 56	264 30	1·869	1·874	1·889	1·880	
Windy Lake	54 37	263 58	1·870	....	1·870	1·870	
Whitefall Portage	54 24	263 34	1·858	1·870	1·879	1·871	
Hairy Lake	54 20	262 50	....	1·857	1·861	1·859	
Old Norway House	53 42	261 59	1·872	1·877	....	1·874	
Lake Winnipeg	53 31	260 48	1·853	1·860	1·872	1·864	
Grand Rapid	53 08	260 32	....	1·876	1·874	1·875	
Cross Lake	53 10	260 28	....	1·877	1·875	1·876	
Cedar Lake	53 18	259 48	....	....	1·871	1·871	
Cumberland House	53 57	257 41	....	1·868	1·866	1·867	
Beaver Lake	54 26	257 50	....	....	1·869	1·869	
Portage des Epinettes	55 04	257 18	....	....	1·871	1·871	
Frog Portage	55 27	256 30	....	....	1·857	1·857	
Little Rock Portage	55 34	255 26	....	....	1·995	1·995	
Great Devil's Portage	55 40	255 12	....	....	1·875	1·875	
Pine Portage	55 43	254 04	....	....	1·884	1·884	
Snake Rapid	55 46	253 30	....	....	1·874	1·874	
Portage Sonnante	55 54	252 24	....	....	1·858	1·858	
Isle à la Crosse	55 25	252 06	....	1·845	1·857	1·851	
Buffaloe Lake	56 04	251 20	....	....	1·854	1·854	
River de la Loche	56 15	250 42	....	....	1·826	1·826	
Portage de la Loche	56 34	250 16	....	....	1·835	1·835	
Clearwater River	56 39	249 11	....	....	1·850	1·850	
Pierre au Calumet	57 24	248 25	....	....	1·938	1·938	
Pointe Brulée	58 07	248 35	....	....	1·852	1·852	
Athabasca	58 43	248 42	....	1·849	1·828	1·838	
1844.							
Fort Vermilion	58 55	243 55	....	....	1·811	1·811	
Fort Dunvegan	55 35	241 35	....	....	1·809	1·809	
Fort Edmonton	53 31	247 08	....	....	1·809	1·809	
Cumberland House	53 57	257 41	....	....	1·853	1·853	
1845.			L. C.	L. D.			
Brockville	44 35	284 15	1·811	1·813	....	1·812	
Cornwall	45 02	285 13	1·821	1·823	....	1·822	
Montreal	45 31	286 25	1·790	1·786	....	1·788	
Quebec	46 49	288 44	1·802	1·800	....	1·801	
Niagara	43 05	280 51	1·821	1·823	....	1·822	
Buffaloe	42 52	281 06	1·814	1·814	....	1·814	
Amherstburg	42 06	276 47	1·823	1·821	....	1·822	
Detroit	42 24	277 02	1·807	1·821	....	1·814	
Port Sarnia	42 58	277 26	1·825	1·824	....	1·825	
Goderich	43 45	278 08	1·828	1·828	....	1·828	

Report relative to the determinations of Absolute Horizontal Force, drawn up by Lieut. I. H. LEFROY, *R.A., and transmitted from Canada in* 1845.

"The measurements of the absolute horizontal force, from September 1842 to March 1843, were made with a transportable magnetometer by MEYERSTEIN of Göttingen, on the plan of Professor WEBER, described in TAYLOR's Scientific Memoirs, Part VIII. The deflecting bar in this instrument was retained at right angles to the meridian, and the angles of deflection were measured upon a long scale carried by the telescope.

"Two deflecting bars were supplied with the instrument, 0·4 inch in diameter and 3·9 and 3·75 inches in length respectively. The angle of deflection was first observed with the farthest end of the deflecting bar at the distance 1·5 foot on the deflection scale; secondly, with the same end at 1·7 foot; and finally with the nearer end at 1·7 foot, giving the following as the distances of the deflecting bar. The bars are distinguished by the letters and numbers marked upon them.

	N. IX. feet.		N. 13. feet.
r =	1·3437	. . . . .	1·3371
r' =	1·5437	. . . . .	1·5371
r'' =	1·8562	. . . . .	1·8629

"The third distance is as nearly in the ratio of 1·32 to the first as the graduation of the scale admitted. The angular value of one division of the scale was 1'·011.

"The following Table contains the weight and dimensions of the magnets and of the stirrup in which they were vibrated, together with those of the small cylindrical brass weights, numbered 5 and 6, used in determining the moment of inertia of the suspended mass.

TABLE XXVIII.

	Length.	Diameter.	Weight.
	ft.	ft.	grs.
Deflecting bar, N. IX.	0·3125	0·0325	1024·4
Deflecting bar, N. 13.	0·3257	0·0354	1092·4
Cylindrical weight, No. 5..	0·1243	0·0342	417·9
Cylindrical weight, No. 6..	0·1245	0·0342	418·2
Stirrup, between the points of suspension	0·3902	......	736·0

"The moment of inertia was found by vibrating each bar with and without the cylindrical weights, and the values of the constant π^2K given by these experiments at various stations are included in the following Table, where

$$K' = \frac{1}{2}(l^2 + r^2)W = \log 1{\cdot}50454,$$

and

$$K = K' \frac{T^2}{T'^2 - T^2} \cdot$$

Table XXIX.

1842 and 1843.	Station.	Bar No. IX.			Bar No. 13.		
		Time of vibration.		π^2K.	Time of vibration.		π^2K.
		Without weights.	With weights.		Without weights.	With weights.	
		s	s		s	s	
September	Quebec....	6·929	13·616	11·024	7·137	13·420	12·465
September	New York .	Not observed.			6·286	11·862	12·314
December	Toronto ..	6·580	12·965	10·942	6·670	11·615	12·239
January ..	Toronto ..	6·617	13·049	11·193	6·728	12·689	12·333
	Means ..	log 2·04348		11·043	log 2·09124		12·338

"Subsequent experience has shown the insufficiency of so small a number of observations as the above, to determine the constant (π^2K) with the requisite degree of precision; but as an improved instrument was substituted in March 1843 for the original transportable magnetometer, and the latter was returned to England at the same time, no opportunity has been afforded for repeating the observations.

"*Experiments of Deflection.*—The observed angles of deflection, multiplied by the ratio $\left(1+\frac{H}{F}\right)$, are given for each station, without any further correction.

"*Experiments of Vibration.*—The observed times of vibration have been corrected for the arc, and for torsion. A note was made of the apparent chord of the arc of vibration as seen through the theodolite, at the beginning and ending of each series, with a few omissions. A movement of the end of the bar through a space equal to its diameter, corresponded to an arc of 12°. When the arcs were not recorded, an approximate value has been taken, viz. for the initial arc 10°, and for the terminal arc 4°. The ratio of the torsion force $\frac{H}{F}$ was observed at one station only, viz. Philadelphia. The same value has been applied at other stations slightly modified for differences of intensity.

"*Temperature.*—The value of the coefficient for changes of temperature was not ascertained. The experiments of vibration and deflection were usually made at short intervals apart, and when both bars were employed, as was generally the case, one was vibrated during the time that the other was in use as a deflector; consequently the correction will generally have been unimportant or counterbalanced on the mean of the two results.

"*Induced Magnetism.*—No correction has been applied for changes in the magnetic moment of the bars, due to their different positions with respect to the earth's inducing force during the two parts of the experiment. This correction was not determined for the bars here employed.

"Gauss's formula for three or more distances* has been employed for the calculation of m and X (the values of the magnetic moment of the deflecting magnet and of the horizontal component of the force). The values of the absolute horizontal force are expressed in the units directed in the Report of the Committee of Physics of the Royal Society, 1840, pp. 21, 22. These values may be converted into their equivalents in the scale more frequently employed by the continental magneticians, by being multiplied by the factor 0·4609.

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* Scientific Memoirs, Part V. Art. II.

Table XXX.—Abstract of the observations to determine the absolute value of the horizontal component of the Magnetic Force with a German transportable magnetometer.

Date.	Station.	Bar.	Angles of deflection.			Corrected time of one vibration.	Temperature.		Values of m.		X.		
			u.	u'.	u''.		Deflection.	Vibration.	N. 13.	N. IX.	Observed.	Mean.	
1842. Sept. 7.	Quebec …	N. IX.	11° 38′·0	7° 42′·6	4° 27′·6	6ˢ·929	62°	62	,,	·756	3·045	3·040	Near the R.A. Barracks
		N. 13.	12 30·3	8 16·9	4 40·6	7·137	62	63	·798	,,	3·035		
16.	Montreal …	N. 13.	11 54·9	7 48·1	4 23·0	7·201	62	62	·776	,,	3·064	3·064	St. Helen's. [tanville.
25.	New York …	N. 13.	9 17·8	6 08·2	3 27·3	6·286	55	58	·779	,,	4·008	4·008	Lun. Asylum, Manhat-
Oct. 1.	Cambridge	N. 13.	10 02·2	6 38·1	3 44·8	6·598	72	65	·774	,,	3·662	3·665	Magnetic observatory.
		N. IX.	9 30·3	6 16·7	3 38·7	6·364	65	72	,,	·744	3·669		
13.	Philadelphia	N. 13.	8 48·3	5 49·5	3 17·5	6·163	55	51	·778	……	4·176	4·176	Magnetic observatory.
Nov. 12.	Chicago*	N. 13.	9 04·3	6 00·3	3 23·5	6·765	29	43	·788	……	4·106	4·106	
		N. IX.	8 29·8	5 35·1	3 15·4	6·752	35	28	,,	·731	4·105		
Oct. 28.	Toronto†	N. 13.	10 23·8	6 52·8	3 53·4	6·718	50	50	·775	,,	3·529	3·532	Magnetic observatory. Mean 3·5365.
		N. IX.	9 38·6	6 27·3	3 44·2	6·509	50	51	,,	·745	3·501		
Dec. 19.	Toronto …	N. 13.	10 22·5	6 52·6	3 53·1	6·680	33	32	·779	,,	3·547		
		N. IX.	9 44·7	6 27·9	3 44·2	6·492	32	33	,,	·738	3·552		
1843. Mar. 25.	Toronto ……	N. IX.	9 17·3	6 11·3	3 34·6	6·633	46	45	,,	·712	3·526	3·541	
27.	Toronto ……	N. IX.	9 21·9	6 12·4	3 35·3	6·621	42	42	,,	·711	3·545		
28.	Toronto ……	N. IX.	9 19·0	6 10·7	3 34·2	6·623	49	46	,,	·710	3·551		
Mar. 25.	Toronto ……	N. 13.	10 15·4	6 47·4	3 50·1	6·730	46	45	·768	,,	3·546		
27.	Toronto ……	N. 13.	10 15·9	6 47·9	3 50·4	6·725	42	41	·772	,,	3·536		
28.	Toronto ……	N. 13.	10 18·0	6 49·1	3 50·8	6·722	48	47	·770	,,	3·541		

"I proceed to the observations of absolute horizontal force made subsequently to March 1833 with a portable unifilar magnetometer, constructed on the principle proposed by Dr. Lamont, in which the deflecting bar is retained at right angles to the suspended bar, and the angles of deflection are read off upon the graduated circle of the base. The lengths of the suspended and deflecting bars were in the ratio of 1 to 1·224, being 2·45 inches and 3·00 inches respectively; but in order to secure an independent check upon the results by these bars, a third deflector of 3·6 inches in length, was also employed, at one distance of deflection only, at many of the stations of observation. It was found that the values of the absolute intensity given by the 3·6 inch bar agreed very satisfactorily with those given by the 3·0 inch bars, and in taking the general mean at each station, an equal weight has been allowed to the results by each bar. The observations were made in the manner described in the instructions for the use of portable instruments by Lieut. C. J. B. Riddell, R.A. The separate parts of each experiment were reduced to a common value of the horizontal force by corresponding observations with a portable bifilar magnetometer, which was previously placed in adjustment at all the stations where it is not otherwise stated; but as a small instrument mounted in the open air is exposed to accidents, and to be much affected by atmospheric changes, it has happened in some instances that breaks and interruptions have occurred in the series, and when the several parts of the experiments were not completed at once, (as at Dunvegan and Isle à la Crosse,) they could not be reduced to a common scale division; at some few stations, where time did not permit of the adjustment of a differential instrument, or other circumstances rendered it inconvenient, the bifilar was not employed.

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* The observations at this station were made by Lieut. Younghusband, R.A. The bar was vibrated in a different stirrup from that commonly employed, and its moment of inertia was afterwards ascertained at Toronto, by vibration of each bar with and without weights: the following were the dimensions; l=3·755 inches; r=0·4095 inches; p=418·0 grains; whence $K'=(\frac{1}{2}l^2+r^2)p=20·594$; and the following were the resulting values of log $\pi^2 K$, by a single set of vibrations with each bar: N. IX.=2·13194; N. 13.=2·17200.

† The observations at Toronto in 1842 have been already published in the Toronto volume for 1840–42. The series in March 1843 was observed by Lieut. Younghusband. The horizontal intensity at Toronto having since been determined with superior instruments, these results are principally interesting for comparison with those obtained at other stations.

"Table XXXVIII. contains the corrected data of each experiment, viz.—

"1. The angles of deflection at each distance, corrected to a temperature of the deflecting bar of 50°, and reduced to a mean value of the differential instrument.

"2. The time of one vibration corrected for the rate of the chronometer, for torsion, and for arc, reduced to a common temperature of 50°, and to the mean value of the differential instrument. The uncorrected data are given in a separate Table, No. XXXIX.

"*Corrections for Temperature.*—The following Table contains the values of the coefficient (q) for changes of temperature for each bar, as obtained by different experiments at Toronto.

Table XXXI.

1845.	No. 30.	No. 31.	No. 17.
January and February	·000226	·000254	·000362
	·000267	·000218	·000378
	·000218	·000224	·000371
	·000225	·000266	·000374
	·000205	·000226	
		·000218	
Means. .	·000228	·000234	·000371

"For bars 20, 23 and 29, employed at Athabasca and M^cKenzie's River, I have assumed a value for q, viz. ·00023.

"*Experiments of Deflection.*—If the lengths of the magnets are in the proportion of 1 to 1·224, each observed angle of deflection furnishes an approximate value of the ratio $\frac{m}{X}$ by the formula $\frac{m}{X} = \frac{1}{2} r^3 \sin u$; but as in the great majority of these observations, the value resulting from the larger distances is greater than that given by the lesser distances, it appears that the correction depending on the distribution of free magnetism in the deflected and suspended bars was not wholly inappreciable. The approximate results have therefore been divided by the coefficient $\left(1 + \frac{P}{r^2}\right)$; the values of the constant P having been derived for each bar from observations at two distances of deflection by the approximate formula $P = -\frac{r^2 r'^5 \sin u' - r'^2 r^5 \sin u}{r'^5 \sin u' - r^5 \sin u}$. These values of P are contained in Table XXXII., in which the values deduced from the observed angles of deflection at some of the latter stations of observation have been included, as well as those resulting from observations made for the purpose at Toronto.

TABLE XXXII.—*Values of* P.

Date.	Station.	No. 30.	No. 31.	No. 17.
1844. September 25.	Rat Portage ..	....	—·0060	
29.	Fort Francis ..	....	—·0038	
October 11.	Fort William ..	—·0054	—·0052	
November 4.	Sault St. Mary..	—·0076	—·0034	
1845. January and February ..	Toronto	—·0011	—·0063	+·0010
	Toronto	—·0019	—·0035	+·0004
	Toronto	—·0063	—·0045	+·0026
	Toronto	—·0068	....	+·0026
	Means....	—·0048	—·0048	+·0016

"The angle of deflection was first observed with the deflecting bar to the east of the suspended magnet, and then to the west; four reversals were commonly made in each position with bars 30 and 31, and five with bar 17, which was employed at one distance only; the mean angle is given in the general table; an intermediate distance was employed at Fort Simpson, viz. 1·1757 foot for each of the two bars, 30 and 31; the distances employed at all the other stations, including those for the spare bars 20, 23 and 29, and for the bars 30, 31 and 17, in the experiments at Toronto in January and March 1845, are contained in the following Table:

TABLE XXXIII.

Bar.	Length.	r.	r′.	r″.	r‴.
	in.	ft.	ft.	ft.	ft.
30	3·0	1·0257	1·3257		
31	3·0	1·0257	1·3257		
17	3·6	1·2514			
20	3·6 hollow.	1·2530			
33	2·45	1·1019	1·4019		
29	2·0	0·9328	1·0828	1·3828	
		Experiments at Toronto.			
30	3·0	1·0257	1·1757	1·3257	
31	3·0	1·0257	1·1257	1·2257	1·3257
17	3·6	1·1514	1·4514		

"*Experiments of Vibration.*—The bars were vibrated in the series of 1843 in a stirrup weighing 322 grains, and similar to the one employed in the observations with the German magnetometer: the moment of inertia was ascertained by vibration with and without cylindrical weights; it has since been re-determined in the method proposed by Dr. LAMONT, employing accurately turned brass rings instead of weights, and the values obtained by the latter method have been applied in preference. The bars were vibrated throughout 1844, and at some of the stations of 1843, without any appendage, the suspension thread being attached by a very light wooden pin, set into the hole which is made in the centre of each for the purpose of fixing it in the stirrup: this method had the advantage of diminishing the time of vibration, and allowing the use of a suspension silk of almost insignificant torsion force; it was found to give greater regularity to the results.

"The moment of inertia of each bar, when vibrated without any appendage, is given by the formula $k=\frac{a^2+b^2}{12}M$: it has also been determined by vibration with the brass rings, the results agreeing very nearly with those determined by measurement.

"The dimensions and weights of the different magnets were as follows:—

TABLE XXXIV.

	Length.	Diameter.	Weight.	Breadth.	Thickness.
	in.	in.	gr.	in.	in.
Bar 30	3·017	0·292	415·3		
31	3·017	0·300	416·7		
17	3·635	0·314	572·5		
20 hollow.	3·672	0·320	252·3		
23	2·446	0·300	337·0		
29	1·977	0·290	271·2		
Ring No. 1	.....	2·986*	289·19	0·195	0·078
3	.....	3·644*	358·78	0·195	0·078
Stirrup.	2·970	Between the points of suspension.			
Weight 5	1·199	0·315	419·9		
6	1·197	0·315			

* Outer diameter.

"From these data we have the following values of K′:—

$$\text{For ring No. 1. } K'=\frac{1}{2}(r^2+r'^2)W=\log 0{\cdot}87111.$$

$$\text{No. 3. } K'=\frac{1}{2}(r^2+r'^2)W=\log 0{\cdot}59442.$$

$$\text{For the stirrup with weights 5 and 6. } K'=\frac{1}{2}(l^2+r^2)W=\log 0{\cdot}80974.$$

The values of K $\left(=K'\frac{T^2}{T'^2-T^2}\right)$ for each magnet, determined by vibration with Dr. LAMONT's rings, were as follows:—

TABLE XXXV.

With the stirrup.		Without the stirrup.			
No. 30.	No. 31.	No. 30.	No. 31.	No. 17.	No. 20.
3·2091 3·2220 3·2169 3·2127 3·2212	3·2375 3·2477 3·2477 3·2371 3·2437	2·1867[b] 2·1867[b] 2·1866[b] 2·1866[b]	2·2154[b] 2·2141[b] 2·2128[b] 2·2145[b]	4·3866[a] 4·3827[b] 4·3880[b] 4·3803[b]	1·9806[b] 1·9804[a] 1·9805[a] 1·9831[b]
3·2163	3·2427	2·1867	2·2142	4·3844	1·9812

[a] Observed with ring No. 1. [b] Observed with ring No. 3.

"The mean values of K in Table XXV. give the following values of the constant log π^2K, which are compared with the approximate values previously obtained by vibration with weights, and by measurement.

TABLE XXXVI.

Vibration.	Bars.	Log π^2K.	
		With rings.	With weights.
With the stirrup......	No. 30	1·50167	1·49830
With the stirrup......	31	1·50521	1·50387
			By measurement.
Without the stirrup ..	30	1·33408*	1·33826
Without the stirrup ..	31	1·33952	1·33995
Without the stirrup ..	17	1·63621	1·63872
Without the stirrup ..	20	1·29122	1·29176

" Both methods of vibration, with the stirrup and without, were employed at several stations, for the sake of comparison, and the horizontal intensity has been deduced from the values of *m* X resulting from each. In the following Table these stations are brought together for the purpose of showing by the agreement in the resulting values of X, the general accuracy of the constants, whether the bar was vibrated in the stirrup, or without it.

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* As this value differs materially from the value given by measurement, the bar was again vibrated Sept. 9, 1845, for the purpose of verification: the resulting value of π^2K was however nearly the same, viz. 1·33442.

TABLE XXXVII.

Date.	Station.	No. 30.				No. 31.			
		Values of X.		Diff. ΔX.	$\frac{\Delta X}{X}$.	Values of X.		Diff. ΔX.	$\frac{\Delta X}{X}$.
		With stirrup.	Without stirrup.			With stirrup.	Without stirrup.		
1843.									
August 16.	Cross Lake	2·348	2·361	+·013	+·006	2·348	2·349	+·001	+·001
23.	Cumberland....	2·345	2·345	·000	·000	2·337	2·337	·000	·000
September 9.	Isle à la Crosse..	2·387	2·397	+·010	+·004	2·387	2·386	—·001	·000
October 12.	Athabasca	2·021	2·025	+·004	+·002	2·027	2·030	+·003	+·001
1844.									
March 2.	Athabasca	2·018	2·025	+·007	+·003	2·020	2·008	—·012	—·006
May 2.	Fort Simpson ..	1·936	1·961	+·025	+·013	1·946	1·966	+·020	+·011
29.	Fort Good Hope.	1·666	1·675	+·009	+·005	1·680	1·680	·000	·000
1845.									
Jan. and Feb.	Toronto	3·528	3·522	—·006	—·002	3·539	3·539	·000	·000
September ..	Toronto	3·510	3·511	—·001	·000	3·514	3·518	·004	—·001

"If we omit the observations at Fort Simpson, at which the difference between the values of X by the two methods of suspension is considerable with both bars, and must have been due to some other cause than a discrepancy between the constants, the mean difference in the values of X, irrespective of signs, is for

$$\text{No. 30.} \quad {\cdot}0029 = \frac{1}{345} \text{ of X,}$$

$$\text{No. 31.} \quad {\cdot}0012 = \frac{1}{833} \text{ of X.}$$

"*Experiments of Vibration.*—Each time of vibration has been corrected for the rate of the chronometer, which was generally large, 10^s to 20^s; and as the chronometer was usually worn in the pocket, under circumstances not favourable to its performance, the actual rate on any given day may have sometimes differed to a sensible amount from the mean rate applied. The arc of vibration was not recorded; but as a general rule it was reduced at the commencement to an apparent value of one diameter of the end of the magnet as seen through the theodolite, which is equivalent to 12°. As the magnet carried no reflector, and there were no direct means of measuring the exact amount of the arc, an approximate correction has been applied, by assuming the mean value of the initial semi-arc 360′, and of the terminal semi-arc as 200′. The same circumstances prevented any direct measurement of the value of $\frac{H}{F}$, but a mean value for each mode of suspension employed was ascertained at Toronto, by trying several suspension threads of the same number of fibres, and of the same silk, as were employed on the Survey.

"The following were the mean values of $\frac{H}{F}$ so obtained:—

	With stirrup.		Without stirrup.
No. 30.	·0022	. . . . . .	·00024.
31.	·0028	. . . . . .	·00030.
17.		. . . . . .	·00031.

"From the above mean values at Toronto, an approximate value has been obtained for each of the other stations by multiplying them by the ratio $\frac{T'^2}{T^2}$ at each station. Thus the value applied at Fort Good Hope for the vibration in the stirrup, was for bar 30, ·0046, and for bar 31, ·0058.

"Table XXXVIII. contains the particulars of all the experiments by which a complete determination of the absolute horizontal force was made; these have been corrected for the various circumstances referred to; and in Table XXXIX. the data are given which have been employed for the corrections in each experiment. Table XXXIX. is followed by a notice of such additional circumstances at any of the stations as may seem to require explanation.

Table XXXVIII.

Exhibiting the corrected data of each experiment for determining the Absolute Horizontal Force. The letter *s* affixed to the time of vibration signifies that the bar was suspended in the stirrup.

Date.	Station.	Bar.	Angles of deflection.	Time of one vibration.	Values of *m*.	Values of X.		
			° ′	s.				
Nov. 4, 1844.	Sault St. Mary	30	13 52·5	4·2527	0·394	3·030	3·029	3·032
4, 1844.	Sault St. Mary	30	6 23·8		0·394	3·028		
4, 1844.	Sault St. Mary	31	12 22·0	not observed	....	3·030	3·031	
4, 1844.	Sault St. Mary	31	5 42·1			3·033		
4, 1844.	Sault St. Mary	17	12 24·8	4·7196	0·639	3·039	3·039	
May 31, 1843.	Fort William	30	17 01·7	4·9311 (*s.*)	0·455	2·868	2·869	2·879
31, 1843.	Fort William	30	7 47·6		0·455	2·871		
31, 1843.	Fort William	31	15 39·8	5·1537 (*s.*)	0·420	2·870	2·872	
31, 1843.	Fort William	31	7 10·4		0·419	2·874		
Oct. 11, 1844.	Fort William	30	14 42·7	4·3471	0·396	2·880	2·880	
11, 1844.	Fort William	30	6 47·1		0·396	2·880		
11, 1844.	Fort William	31	13 00·9	4·6387	0·352	2·882	2·878	
11, 1844.	Fort William	31	6 01·0		0·353	2·874		
11, 1844.	Fort William	17	13 13·0	4·8517	0·640	2·862	2·862	
June 14, 1843.	Fort Francis	30	15 59·3	4·7821	0·455	3·049	3·048	3·041
14, 1843.	Fort Francis	30	7 21·4		0·456	3·046		
14, 1843.	Fort Francis	31	14 38·0	5·0102	0·418	3·051	3·049	
14, 1843.	Fort Francis	31	6 45·1		0·418	3·047		
Sept. 29, 1844.	Fort Francis	30	13 55·6	4·2395	0·396	3·034	3·031	
29, 1844.	Fort Francis	30	6 26·4		0·397	3·027		

TABLE XXXVIII. (Continued.)

Date.	Station.	Bar.	Angles of deflection.	Time of one vibration.	Values of *m*.	Values of X.		
			° ′	s.				
Sept. 29, 1844.	Fort Francis	31	12 16·3	4·5242	0·351	3·044	3·045	3·041
29, 1844.	Fort Francis	31	5 39·5		0·351	3·045		
29, 1844.	Fort Francis	17	12 23·9	4·7110	0·640	3·046	3·046	
25, 1844.	Rat Portage	30	14 48·7	4·3592	0·397	2·863	2·864	2·873
25, 1844.	Rat Portage	30	6 48·1		0·396	2·865		
25, 1844.	Rat Portage	31	13 00·7	4·6466	0·352	2·880	2·880	
25, 1844.	Rat Portage	31	6 00·0		0·351	2·879		
25, 1844.	Rat Portage	17	13 11·1	4·8392	0·642	2·877	2·877	
June 21, 1843.	River Winnipeg....	30	16 34·9	not observed	0·395	2·941	2·938	2·938
21, 1843.	River Winnipeg....	30	7 36·6			2·935		
Sept. 19, 1844.	Fort Alexander	30	15 36·3	4·4898	0·397	2·710	2·702	2·700
19, 1844.	Fort Alexander	30	7 15·2			2·694		
19, 1844.	Fort Alexander	31	13 51·8	4·7943	0·351	2·706	2·704	
19, 1844.	Fort Alexander	31	8 23·7		0·352	2·703		
19, 1844.	Fort Alexander	17	14 06·4	5·0090	0·641	2·689	2·689	
June 30, 1843.	Upper Fort Garry ..	30	16 55·2	4·9748 (*s.*)	0·450	2·851	2·849	2·849
30, 1843.	Upper Fort Garry ..	30	7 47·4		0·451	2·846		
30, 1843.	Upper Fort Garry ..	31	15 35·1	5·1938	0·416	2·851	2·849	
30, 1843.	Upper Fort Garry ..	31	7 11·7		0·417	2·848		
July 14, 1843.	Norway House	30	19 20·0	6·1351 (*s.*)	0·439	2·179	2·174	2·174
14, 1843.	Norway House	30	8 50·2		0·441	2·169		
14, 1843.	Norway House	31	21 49·6	5·7609 (*s.*)	0·391	2·177	2·178	
14, 1843.	Norway House	31	10 01·4		0·390	2·179		
Sept. 6, 1844.	Norway House	30	19 37·7	5·0058	0·396	2·176	2·173	
6, 1844.	Norway House	30	9 00·7		0·397	2·171		
6, 1844.	Norway House	31	17 23·6	5·3569	0·351	2·168	2·170	
6, 1844.	Norway House	31	7 57·5		0·351	2·170		
6, 1844.	Norway House	17	17 34·0	5·5516	0·644	2·180	2·180	
July 26, 1843.	York Factory	30	32 09·9	6·9613 (*s.*)	0·435	1·507	1·509	1·523
26, 1843.	York Factory	30	14 13·7		0·434	1·510		
26, 1843.	York Factory	31	28 45·5	7·2275 (*s.*)	0·400	1·533	1·537	
26, 1843.	York Factory	31	12 48·2		0·398	1·538		
Aug. 16, 1843.	Cross Lake	31	17 52·7	5·8808 (*s.*)	0·391	2·348	2·348	2·352
16, 1843.	Cross Lake	31	8 11·9		0·391	2·347		
16, 1843.	Cross Lake	30	19 45·6	5·6034 (*s.*)	0·430	2·349	2·348	
16, 1843.	Cross Lake	30	9 02·5		0·431	2·347		
16, 1843.	Cross Lake	31	17 52·7	4·8516	0·393	2·351	2·349	
16, 1843.	Cross Lake	31	8 11·9		0·393	2·348		
16, 1843.	Cross Lake	30	19 45·6	4·6167	0·431	2·362	2·361	
16, 1843.	Cross Lake	30	9 02·3		0·431	2·361		
23, 1843.	Cumberland House	30	19 46·3	5·5994 (*s.*)	0·431	2·347	2·345	2·341
23, 1843.	Cumberland House	30	9 05·0		0·432	2·343		
23, 1843.	Cumberland House	31	18 12·1	5·9089 (*s.*)	0·394	2·327	2·337	
23, 1843.	Cumberland House	31	8 10·7		0·390	2·348		
23, 1843.	Cumberland House	30	19 46·3	4·6163	0·431	2·347	2·345	
23, 1843.	Cumberland House	30	8 05·0		0·432	2·343		
23, 1843.	Cumberland House	31	18 12·1	4·8845	0·394	2·326	2·337	
23, 1843.	Cumberland House	31	8 10·7		0·390	2·348		
26, 1844.	Carlton House	30	15 28·1	4·4542	0·396	2·743	2·743	2·746
26, 1844.	Carlton House	30	7 06·5		0·397	2·743		
26, 1844.	Carlton House	31	13 33·8	4·7654	0·350	2·751	2·750	
26, 1844.	Carlton House	31	6 15·7		0·350	2·748		
17, 1844.	Edmonton House ..	30	14 25·7	4·2948	0·397	2·943	2·941	2·945
17, 1844.	Edmonton House ..	30	6 39·6		0·398	2·939		
17, 1844.	Edmonton House ..	31	12 20·1	4·5935	0·350	2·956	2·953	
17, 1844.	Edmonton House ..	31	5 51·1		0·351	2·949		
17, 1844.	Edmonton House ..	17	13 28·5	4·6876	0·670	2·938	2·938	
Sept. 9, 1843.	Isle à la Crosse	30	18 46·8	5·6434 (*s.*)	0·417	2·390	2·387	2·386
9, 1843.	Isle à la Crosse	30	8 38·8		0·418	2·382		
9, 1843.	Isle à la Crosse	31	17 16·5	5·9081 (*s.*)	0·384	2·386	2·387	
9, 1843.	Isle à la Crosse	31	7 55·1		0·384	2·387		

TABLE XXXVIII. (Continued.)

Date.	Station.	Bar.	Angles of deflection.	Time of one vibration.	Values of m.	Values of X.		
			° ′	s.				
Sept. 9, 1843.	Isle à la Crosse	30	18 46·8	4·6589	0·419	2·402	2·397	2·386
9, 1843.	Isle à la Crosse	30	8 38·8		0·420	2·392		
9, 1843.	Isle à la Crosse	31	17 16·5	4·8838	0·384	2·386	2·386	
9, 1843.	Isle à la Crosse	31	7 55·1		0·384	2·386		
Oct. 13, 1843.	Athabasca	30	22 26·8	6·1381 ($s.$)	0·418	2·018	2·021	2·022
13, 1843.	Athabasca	30	10 08·6		0·416	2·024		
13, 1843.	Athabasca	31	20 26·7	6·4017 ($s.$)	0·385	2·031	2·027	
13, 1843.	Athabasca	31	9 34·8		0·386	2·023		
13, 1843.	Athabasca	30	22 26·8	5·0514	0·418	2·022	2·025	
13, 1843.	Athabasca	30	10 08·6		0·417	2·028		
13, 1843.	Athabasca	31	20 26·7	5·2816	0·385	2·034	2·030	
13, 1843.	Athabasca	31	9 34·8		0·387	2·026		
March 1, 1844.	Athabasca	30	22 32·1	6·1234 ($s.$)	0·419	2·019	2·018	
1, 1844.	Athabasca	30	10 15·0		0·419	2·018		
1, 1844.	Athabasca	31	20 13·6	6·4728 ($s.$)	0·378	2·019	2·020	
1, 1844.	Athabasca	31	9 12·6		0·378	2·021		
1, 1844.	Athabasca	30	22 32·1	5·0328	0·421	2·025	2·025	
1, 1844.	Athabasca	30	10 15·0		0·421	2·025		
1, 1844.	Athabasca	31	20 13·6	5·3740	0·376	2·009	2·008	
1, 1844.	Athabasca	31	9 12·6		0·376	2·007		
July 2, 1844.	Athabasca	30	20 10·0	5·1507	0·399	2·039	2·040	2·040
2, 1844.	Athabasca	30	9 37·4		0·399	2·041		
2, 1844.	Athabasca	31	18 44·7	5·4725	0·356	2·044	2·040	
2, 1844.	Athabasca	31	8 38·6		0·357	2·036		
2, 1844.	Athabasca	17	19 36·0	5·6326	0·669	2·038	2·038	
Oct. 14, 1843.	Athabasca	20	15 05·5	4·3373	0·515	2·017	2·017	2·017
14, 1843.	Athabasca	23	8 40·6	5·2689	0·206	2·042	2·038	2·038
14, 1843.	Athabasca	23	4 14·2		0·207	2·034		
14, 1843.	Athabasca	29	10 51·3	4·4147	0·155	2·034	2·029	2·029
14, 1843.	Athabasca	29	6 57·3		0·156	2·025		
14, 1843.	Athabasca	29	3 20·0		0·156	2·028		
July 12, 1844.	Fort Vermilion	30	19 17·6	4·9000	0·401	2·240	2·244	2·250
12, 1844.	Fort Vermilion	30	8 45·4		0·400	2·248		
12, 1844.	Fort Vermilion	31	17 01·5	5·1890	0·359	2·261	2·259	
12, 1844.	Fort Vermilion	31	7 50·5		0·360	2·257		
12, 1844.	Fort Vermilion	17	17 43·4	5·3771	0·668	2·241	2·241	
23, 1844.	Fort Dunvegan	30	15 39·8	4·4557	0·399	2·725	2·722	2·724
23, 1844.	Fort Dunvegan	30	7 13·8		0·400	2·719		
23, 1844.	Fort Dunvegan	31	13 49·1	4·7671	0·353	2·725	2·725	
23, 1844.	Fort Dunvegan	31	6 21·7		0·353	2·725		
23, 1844.	Fort Dunvegan	17	14 36·5	4·8589	0·673	2·725	2·725	
June 22, 1844.	Fort Resolution	30	24 46·9	5·5320	0·400	1·761	1·762	1·763
22, 1844.	Fort Resolution	30	11 12·5		0·400	1·762		
22, 1844.	Fort Resolution	31	22 04·0	5·8714	0·359	1·764	1·765	
22, 1844.	Fort Resolution	31	10 01·9		0·359	1·765		
22, 1844.	Fort Resolution	17	22 51·3	6·0479	0·671	1·764	1·764	
20, 1844.	Big Island	30	23 00·3	....	....	1·894	1·891	1·891
20, 1844.	Big Island	31	20 32·4	....	....	1·888		
May 2, 1844.	Fort Simpson	30	23 06·5	6·3133 ($s.$)	1·412	1·935	1·936	1·952
2, 1844.	Fort Simpson	30	15 6·7		1·412	1·936		
2, 1844.	Fort Simpson	30	10 27·0		1·411	1·939		
2, 1844.	Fort Simpson	31	20 27·6	6·6867 ($s.$)	0·368	1·944	1·946	
2, 1844.	Fort Simpson	31	13 22·9		0·367	1·948		
2, 1844.	Fort Simpson	31	9 19·1		0·368	1·945		
2, 1844.	Fort Simpson	30	23 06·5	5·1393	0·417	1·960	1·961	
2, 1844.	Fort Simpson	30	15 06·7		0·417	1·960		
2, 1844.	Fort Simpson	30	10 27·0		0·416	1·964		
2, 1844.	Fort Simpson	31	20 27·6	5·4691	0·372	1·961	1·966	
2, 1844.	Fort Simpson	31	13 22·9		0·372	1·970		
2, 1844.	Fort Simpson	31	9 19·1		0·372	1·968		
2, 1844.	Fort Simpson	17	20 57·3	5·6751	0·686	1·959	1·959	

TABLE XXXVIII. (Continued.)

Date.	Station.	Bar.	Angles of deflection.	Time of one vibration.	Values of *m*.	Values of X.		
			° ′	s.				
June 12, 1844.	Fort Simpson	30	22 26·9	5·2323	0·401	1·952	1·954	1·952
12, 1844.	Fort Simpson	30	10 10·3		0·403	1·957		
12, 1844.	Fort Simpson	31	20 03·3	5·5993	0·360	1·936	1·943	
12, 1844.	Fort Simpson	31	9 02·2		0·358	1·949		
12, 1844.	Fort Simpson	17	20 36·6	5·7305	0·674	1·956	1·956	
12, 1844.	Fort Simpson	20	13 55·2	4·6155	0·465	1·972	1·972	
12, 1844.	Fort Simpson	23	8 35·1	5·5003	0·196	1·967	1·947	
12, 1844.	Fort Simpson	23	4 19·3		0·200	1·928		
May 28, 1844.	Fort Norman	30	25 36·5	5·4832	0·409	1·753	1·760	1·760
June 2, 1844.	Fort Norman	31	22 10·5	5·8403	0·362	1·768		
May 29, 1844.	Fort Good Hope ..	30	26 44·2	6·8206 (*s.*)	0·408	1·669	1·666	1·676
29, 1844.	Fort Good Hope ..	30	12 10·7		0·410	1·664		
29, 1844.	Fort Good Hope ..	31	23 31·0	7·2323 (*s.*)	0·364	1·682	1·680	
29, 1844.	Fort Good Hope ..	31	10 42·4		0·364	1·679		
29, 1844.	Fort Good Hope ..	30	26 44·2	5·6013	0·409	1·679	1·675	
29, 1844.	Fort Good Hope ..	30	12 10·7		0·412	1·671		
29, 1844.	Fort Good Hope ..	31	23 31·0	5·9763	0·364	1·682	1·680	
29, 1844.	Fort Good Hope ..	31	10 42·4		0·364	1·679		
Jan. 22, 1845.	Toronto	30	11 56·0	4·7712 (*s.*)	0·395	3·527	3·528	3·528
22, 1845.	Toronto	30	7 54·2		0·395	3·526		
22, 1845.	Toronto	30	5 29·9		0·395	3·530		
23, 1845.	Toronto	30	11 56·1	4·7699 (*s.*)	0·395	3·528	3·529	
23, 1845.	Toronto	30	7 53·9		0·395	3·529		
23, 1845.	Toronto	30	5 30·1		0·395	3·530		
25, 1845.	Toronto	30	11 53·7	4·7735 (*s.*)	0·395	3·531	3·529	
25, 1845.	Toronto	30	7 52·7		0·395	3·530		
25, 1845.	Toronto	30	5 29·4		0·395	3·526		
29, 1845.	Toronto	30	11 53·0	4·7809 (*s.*) 3·9463	0·394	3·525	3·525	
29, 1845.	Toronto	30	7 51·6		0·394	3·527		
29, 1845.	Toronto	30	5 29·2		0·394	3·522		
Feb. 3, 1845.	Toronto	31	10 32·4	5·0857 (*s.*)	0·350	3·533	3·535	3·539
3, 1845.	Toronto	31	7 56·9		0·350	3·535		
3, 1845.	Toronto	31	6 09·2		0·350	3·536		
3, 1845.	Toronto	31	4 51·4		0·350	3·537		
6, 1845.	Toronto	31	10 28·9	5·0850 (*s.*)	0·349	3·543	3.543	
6, 1845.	Toronto	31	7 55·1		0·349	3·542		
6, 1845.	Toronto	31	6 07·7		0·349	3·543		
6, 1845.	Toronto	31	4 50·7		0·350	3·543		
8, 1845.	Toronto	31	10 29·2	5·0925 (*s.*)	0·349	3·537	3·538	
8, 1845.	Toronto	31	7 54·9		0·349	3·538		
8, 1845.	Toronto	31	6 07·5		0·349	3·538		
8, 1845.	Toronto	31	4 50·5		0·348	3·538		
3, 1845.	Toronto	31	10 32·4	4·2031	0·350	3·533	3·535	3·539
3, 1845.	Toronto	31	7 56·9		0·350	3·535		
3, 1845.	Toronto	31	6 09·2		0·350	3·535		
3, 1845.	Toronto	31	4 51·4		0·350	3·537		
8, 1845.	Toronto	31	10 29·2	4·2051	0·349	3·539	3·540	
8, 1845.	Toronto	31	7 54·9		0·349	3·540		
8, 1845.	Toronto	31	6 07·5		0·349	3·541		
8, 1845.	Toronto	31	4 50·5		0·349	3·540		
March 11, 1845.	Toronto	31	10 27·9	4·2051	0·349	3·543	3·543	
11, 1845.	Toronto	31	4 50·1		0·348	3·543		
4, 1845.	Toronto	17	13 43·7	4·3815	0·639	3·533	3·533	3·535
4, 1845.	Toronto	17	6 48·0		0·639	3·533		
8, 1845.	Toronto	17	13 39·3	4·3879	0·636	3·534	3·534	
8, 1845.	Toronto	17	6 46·1		0·636	3·533		
10, 1845.	Toronto	17	13 38·6	4·3841	0·636	3·539	3·539	
10, 1845.	Toronto	17	6 45·2		0·636	3·540		
11, 1845.	Toronto	17	13 39·5	4·3897	0·636	3·532	3·533	
11, 1845.	Toronto	17	6 46·4		0·636	3·533		

TABLE XXXIX.; exhibiting the uncorrected particulars of each experiment in Table XXXVIII.

Date.	Station.	Bifilar Magnetometer.			Bar.	Experiments of Deflection.								Experiments of Vibration.					Rate of chronometer.
		Mean readings.		Value of 1 sc. div. in parts of H. F.		u′.	Therm.	Bifilar.		u′.	Therm.	Bifilar.		Time of one vibration.	Number.	Temperature.	Bifilar.		
		Scale.	Therm.					Scale.	Therm.			Scale.	Therm.				Scale.	Therm.	
Nov. 4, 1844.	Sault St. Mary	170·7	40·4	·00025	30	13° 50′·3	45°·0	178·9	45°·0	8° 22′·1	44°·6	183·8	44°·6	s 4·2524	5×200	45°	261·8	45°·0	s −17
4, 1844.	Sault St. Mary	....	....	....	31	12 14·8	47·0	196·5	47·6	5 39·2	47·0	193·2	46·8						
4, 1844.	Sault St. Mary	....	....	....	17	12 24·3	47·0	183·2	47·0	....	....	....	....	4·7081	11×200	42	175·1	42·0	
May 31, 1843.	Fort William	254·0	55·0	·00057	30	17 01·9	55·0	231·8	55·0	7 47·4	55·0	252 6	55·0	4·9331(s.)	476	55·0	253·0	54·0	− 6
31, 1843.	Fort William	....	....	....	31	15 33·6	50·0	265·2	55·0	7 10·6	50·0	253·8	54·0	5·1600(s.)	360	55·0	247·3	55·0	
Oct. 11, 1844.	Fort William	....	....	....	30	14 41·8	55·0	....	....	6 46·7	55·0	....	....	4·3470	10×200	40·0	....	....	−10
11, 1844.	Fort William	....	....	....	31	13 00·8	51·0	....	....	6 01·2	47·0	....	....	4·6370	11×202	38·0			
11, 1844.	Fort William	....	....	....	17	13 08·3	65·5	....	....	....	....	....	....	4·8462	11×200	36·0			
June 14, 1843.	Fort Francis	203·0	60·0	·00044	30	15 56·3	62·0	203·8	60·3	7 20·2	61·0	202·7	61·0	4·7865(s.)	206	62·0	....	....	− 6
14, 1843.	Fort Francis	....	....	....	31	14 36·5	60·0	202·5	58·0	6 44·3	60·0	203·6	57·0	5·0094(s.)	470	62·0	203·8	62·0	
Sept. 20, 1844.	Fort Francis	....	....	....	30	13 57·1	42·0	....	....	6 27·1	42·0	....	....	4·2423	11×200	55·0	....	....	−11
20, 1844.	Fort Francis	....	....	....	31	12 15·4	55·0	....	....	5 39·1	55·0	....	....	4·5272	11×200	55·0			
20, 1844.	Fort Francis	....	....	....	17	12 22·5	55·0	....	....	....	....	....	....	4·7201	11×200	60·0			
25, 1844.	Rat Portage	....	....	....	30	14 50·0	43·5	....	....	6 48·7	43·5	....	....	4·3572	11×196	45·0	....	....	−11
25, 1844.	Rat Portage	....	....	....	31	13 01·6	44·0	....	....	6 00·5	44·0	....	....	4·6442	11×196	45·0			
25, 1844.	Rat Portage	....	....	....	17	13 12·6	45·0	....	....	....	....	....	....	4·8350	9×200	45·0			
June 21, 1843.	River Winnipeg	....	....	....	30	16 30·8	68·0	....	....	7 34·8	68·0								
Sept. 19, 1844.	Fort Alexander	208·0	49·0	−·00064	30	15 39·2	55·0	216·6	55·0	7 12·4	55·0	202·0	55·0	4·4958	11×200	49·3	212·0	49 0	− 8
19, 1844.	Fort Alexander	....	....	....	31	13 49·8	49·0	201·1	49·0	6 23·4	46·0	204·1	46 0	4·7930	10×226	53·0	207·2	53·0	
19, 1844.	Fort Alexander	....	....	....	17	14 06·6	42·6	201·8	42·6	....	....	....	....	4·9997	11×200	45·0	214·6	45·0	
June 30, 1843.	Upper Fort Garry	203·3	69·5	·00041	30	16 50·4	73·4	199·3	73·4	7 45·7	73·0	199·0	70·2	8·6026(s.)	206	61·7	201·3	61·7	−12
30, 1843.	Upper Fort Garry	....	....	....	31	15 26·8	72·0	209·4	74·0	7 07·6	74·4	208·7	76·4	5·1960(s.)	330	66·0	203·2	66 0	
July 14, 1843.	Norway House	235·0	83·0	·00086	30	21 29·7	85·0	212·0	85·1	9 48·0	86·0	250·6	86·3	5·7957(s.)	6×100	79·0	226·4	79·5	−12
14, 1843.	Norway House	....	....	....	31	*19 22·0	83·0	224·1	83·0	8 52·7	82·5	227·8	82·5	6·1230(s.)	7×100	85·0	245·5	85·0	
Sept. 6, 1844.	Norway House	237·0	49·5	·00018	30	19 37·2	56·0	220·2	56·0	8 59·9	56·0	229·2	56·0	4·9995	11×200	53·8	249·4	53·8	−11
6, 1844.	Norway House	....	....	....	31	17 14·5	58·0	249·2	58·0	7 54·5	61·0	242·1	61·0	5·3575	10×200	53·5	235·5	53·5	
6, 1844.	Norway House	....	....	....	17	17 34·7	54·5	236·4	54·5	....	....	....	....	5·5881	11×200	56·0	193·6	56·1	
July 26, 1843.	York Factory	222·0	74·0	·00083	30	32 05·6	72·5	218·9	72·3	14 11·3	76·0	218·3	74·3	6·9628(s.)	6×100	74·5	221·1	74·5	−12
26, 1843.	York Factory	....	....	....	31	28 32·1	74·3	223·7	74·3	12 42·6	74·0	230·8	74·0	7·2244(s.)	11×102	73 0			
Aug. 16, 1843.	Cross Lake	....	....	....	31	17 49·2	63·5	....	....	8 10·2	64·5	....	....	5·6076(s.)	9×100	68·0	....	....	−10
16, 1843.	Cross Lake	....	....	....	31									4·6261	10×100	67·0			
16, 1843.	Cross Lake	....	....	....	30	19 41·7	64·0	....	....	9 00·8	64·0	....	....	5·8784(s.)	8×100	60·0			
16, 1843.	Cross Lake	....	....	....	30									4·8605	8×100	65·0			
23, 1843.	Cumberland House	216·0	63·0	·00034	30	19 45·8	64·0	213·8	64·0	9 03·5	61·0	213·7	64·0	5·6038(s.)	4×166	60·0	212·2	60·0	−15
23, 1843.	Cumberland House	....	....	....	30									4·6202	10×200	61·5	221·3	61·5	
23, 1843.	Cumberland House	....	....	....	31	18 09·4	68·0	206·8	68·5	8 08·8	66·5	213·4	66·5	5·9056(s.)	10×200	60·5	219 0	60·5	
23, 1843.	Cumberland House	....	....	....	31									4·8819	11×200	58·3	228·1	58·3	
26, 1844.	Carlton House	....	....	....	30	15 26·4	57·5	....	....	7 05·7	58·5	....	....	4·4645	11×200	70·0	....	....	−17
26, 1844.	Carlton House	....	....	....	31	13 31·9	60·0	....	....	6 14·6	62·0	....	....	4·7767	11×200	70 0			
17, 1844.	Fort Edmonton	193·0	52·0	·00041	30	14 29·0	53·2	181·8	53·2	6 40·6	55·6	181·8	55·6	4·2947	10×200	47·7	195 4	47·1	−12
17, 1844.	Fort Edmonton	....	....	....	31	12 34·7	61·0	190·5	61·0	5 49·0	59·2	198·0	59 2	4·5938	11×196	46 8	193·8	46·8	
17, 1844.	Fort Edmonton	....	....	....	17	13 24·4	55·0	199·0	55·0	....	....	....	....	4·6859	10×200	45·6	194·7	45·6	
Sept. 9, 1843.	Isle à la Crosse	248·2	69·2	·00037	30	18 46·1	73·0	233·2	73·0	8 34·5	73·5	253·2	73·5	5·6378(s.)	11×200	54·0	....	....	−22
9, 1843.	Isle à la Crosse	....	....	....	......	....	....	....	....	....	....	....	....	4·6655	11×300	66·5	252·2	66·5	
9, 1843.	Isle à la Crosse	....	....	....	31	17 11·2	72·7	245·8	72·7	7 52·3	72·0	247·8	72·0	5·8993	10×200	64·0			
9, 1843.	Isle à la Crosse	....	....	....	......	....	....	....	....	....	....	....	....	4·8900	10×250	64·0	252·8	64·0	
Oct. 13, 1843.	Athabasca	176·0	64·6	·00037	30	22 28·2	38·0	185·2	57·2	10 13·0	38·0	166·2	57·7	6·0913(s.)	11×200	34·0	277·2	50·4	+10
13, 1843.	Athabasca	....	....	....	......	....	....	....	....	....	....	....	....	5 0351	11×200	38·0	267·4	55·0	
13, 1843.	Athabasca	....	....	....	31	20 31·0	36·6	175·0	65·2	9 23·7	36·4	186·1	66·5	6·3767(s.)	11×200	31·0	258·1	48·3	
13, 1843.	Athabasca	....	....	....	......	....	....	....	....	....	....	....	....	5·2109	10×231	37·0	294·4	51·4	
13, 1843.	Athabasca	....	....	....	20	15 05·9	36·8	178·6	73·0	....	....	....	....	4·3302	4×200	40·0	286·5	50·4	
14, 1843.	Athabasca	254·4	50·4	·00037	23	8 42·9	37·0	244·0	61·0	4 15·5	36·0	241·3	60·0	5·2600	11×160	40·0	....	....	+10
14, 1843.	Athabasca	....	....	....	29	10 54·7	37·0	243·5	58·6	6 59·5	37·0	243·2	58·0	4·4067	11×200	40·0			
14, 1843.	Athabasca	....	....	....	......	....	....	....	....	3 21·0	37·0	213·5	59·0	....	....	....	....	....	−34*

TABLE XXXIX., exhibiting the uncorrected particulars of each experiment in Table XXXVIII. (Continued.)

Date.	Station.	Bifilar Magnetometer.			Bar.	Experiments of Deflection.								Experiments of Vibration.					Rate of chronometer.
		Mean readings.		Value of 1 sc. div. in parts of H. F.		u.	Therm.	Bifilar.		u′.	Therm.	Bifilar.		Time of one vibration.	Number.	Temperature.	Bifilar.		
		Scale.	Therm.					Scale.	Therm.			Scale.	Therm.				Scale.	Therm.	
March 1, 1844.	Athabasca				30	22° 34′·8	41°·8		°	10° 15′·8	43°·8		°	s 6·1011(s.)	10×100	29°·0		°	+15°
1, 1844.	Athabasca													5·0258	11×200	34·5			
1, 1844.	Athabasca				31	20 14·9	45·4			9 13·5	45·4			6·4381(s.)	10×100	29·0			
1, 1844.	Athabasca													5·3643	11×200	31·8			
July 2, 1844.	Athabasca	232·0	58·3	·00043	30	21 14·5	57·0	220·8	57·0	9 39·3	57·0	221·3	57·0	5·1569	11×200	61·0	232·6	59·0	− 3
2, 1844.	Athabasca				31	18 45·5	59·0	224·8	59·0	8 38·2	59·0	227·5	59 0	5·4781	11×200	63·0	233·8	59·0	
2, 1844.	Athabasca				17	19 34·7	59·0	226·2	59 0					5·6196	9×200	65·0	231·4	59·0	
12, 1844.	Fort Vermilion	174·2	90·0	·00048	30	19 01·8	78·0	181·2	94·0	8 41·9	78·0	172·8	94·0	4·9238	11×234	77·0	169·8	85·0	− 3
12, 1844.	Fort Vermilion				31	16 57·3	78·0	166·8	98·0	7 47·8	77·0	173·1	95·0	5·2116	11×206	78·0	173·6	80 0	
12, 1844.	Fort Vermilion				17	17 31·6	79·0	174·7	92·0					5·4065	10×100	75·0	181·7	80·0	
23, 1844.	Dunvegan	167·4	77·0	−·00044	30	15 33·3	79·0	170·7	81·0	7 09·7	79·0	163·8	82 0	4·4496	10×200	48·0	153·2	48·0	− 3
24, 1844.	Dunvegan	166·1	60·0		31	13 40·8	74·0	157·2	76·0	6 18·3	74·0	159·0	76·0	4·7630	11×200	50·5	156·3	50·5	
24, 1844.	Dunvegan				17	14 31·2	63·0	157·6	63·0					4·8658	11×196	58·0	161·4	58·0	
June 22, 1844.	Fort Resolution	226·0	60·0	·00031	30	24 50·0	51·0	221·4	57·0	11 14·7	51·0	215·0	57·0	5·5218	11×200	51·0	238·0	62·0	− 1
22, 1844.	Fort Resolution				31	22 04·6	51·0	226·1	57·0	10 03·3	51·0	229·7	57·0	5·8695	6×220	51·0	227·0	63·0	
22, 1844.	Fort Resolution				17	22 49·8	51·0	230·8	57·0					6·0505	7×200	51·0	221·3	64·4	
20, 1844.	Big Island				30	22 52·0	75·0												
20, 1844.	Big Island				31	20 25·1	75·0												
May 2, 1844.	Fort Simpson	246·0	64·6	−·00028	30	23 09·8	37·5	240·5	60·5	10 28·8	37·5	244·7	62·6	6·3020(s.)	11×200	47·0	245·6	64·6	+15
2, 1844.	Fort Simpson									15 07·8	38·0	242·0	66·2	5·1307	11×200	39·0	240·2	61·0	
2, 1844.	Fort Simpson				31	20 14·2	48·5	209·1	69·0	9 12·5	48·5	201·7	67·0	6·6707(s.)	11×200	46 0	215·6	65·0	
2, 1844.	Fort Simpson									13 14·4	44·0	201·8	65·8	5·4616	11×200	42·0	211·3	63·0	
2, 1844.	Fort Simpson				17	20 43·3	40·0	194·3	64·0					5·6680	11×222	43·0	243·7	65·0	
June 12, 1844.	Fort Simpson	140·0	57·8	−·00055	30	22 30·6	57·5	147·3	56·4	10 12·0	57·5	147·5	56·4	5·2357	11×200	57·8	138·9	57·8	− 8
12, 1844.	Fort Simpson				31	20 05·1	56·0	144·4	56·0	9 01·8	57·0	141·4	57·0	5·5815	11×200	58·8	127·6	60·4	
12, 1844.	Fort Simpson				17	20 34·8	56·0	141·2	57·0					5·7256	11×200	58·0	130·8	60·6	
14, 1844.	Fort Simpson	133·4	61·9	−·00055	20	13 57·2	68·5	126·9	65·0					4·6234	11×200	67·0	130·4	57·0	− 8
14, 1844.	Fort Simpson				23	8 32·6	70·0	134·2	65·0	4 18·1	70·0	134·3	65·6	5·5088	10×160	67·0	131·5	57·0	
May 28, 1844.	Fort Norman				30	25 39·2	43·0							5·1752	11×200	36·0			− 3
June 2, 1844.	Fort Norman				31	22 15·2	36·0							5·8379	11×200	36·0			
May 29, 1844.	Fort Good Hope	211·5	46·0	−·00027	30	26 53·6	44·0	227·0	47·0	12 14·2	44·0	221·4	43·5	6·8015(s.)	550	37·0	208·2	37·0	− 3
29, 1844.	Fort Good Hope													5·5961	10×152	37·0	207·3	37·0	
29, 1844.	Fort Good Hope				31	23 36·0	41·5	212·6	41·5	10 42·0	41·5	197·1	41·5	7·2046(s.)	10×202	37·5	205·0	37·5	
29, 1844.	Fort Good Hope													5·9640	10×100	36·6	200·3	36·6	
Jan. 22, 1845.	Toronto	574·6	46·6	·000087	30	11 54·4	55·4	570·8	45·6	7 52·2	62·5	572·7	47·1	4·7638(s.)	382	54·5	577·9	47·9	−14
22, 1845.	Toronto									5 28·7	61·2	572·8	45·8						
28, 1845.	Toronto	570·4	46·4			11 54·8	50·2	573·3	47·3	7 53·7	45·8	570·8	46·2	4·7621(s.)	350	50·0	573·0	47·0	−85
28, 1845.	Toronto									5 30·1	44·0	567·6	46·9						
25, 1845.	Toronto	574·0	41·1			11 52·9	58·2	563·4	42·1	7 51·9	54·1	577·8	42·2	4·7653(s.)	400	45·0	576·7	42·8	−9·0
25, 1845.	Toronto									5 29·0	52·6	574·4	43·2						
29, 1845.	Toronto	570·0	43·9			11 51·3	60·7	561·1	45·2	7 50·0	65·5	562·2	45·3	4·7741(s.)	320	56·0	564·2	46 3	−10·0
29, 1845.	Toronto									5 27·2	67·3	562·6	45·3	3·9460	318	56·0	562·8	45·9	−10·0
Feb. 3, 1845.	Toronto	593·5	34·7		31	10 32·8	47·1	591·2	34·3	7 56·8	49·9	596·7	34·9	5·0787(s.)	350	47·3	592·2	39·0	− 7·3
3, 1845.	Toronto					6 08·6	53·4	598·0	31·8	4 50·8	55·5	598·1	34·9	4·2013	350	51·0	592·6	37·5	− 7·3
6, 1845.	Toronto	594·7	33·1			10 29·5	46·7	596·5	32·6	7 55·4	47·0	597·3	33·2	5·0730(s.)	356	31·8	591·3	31·4	− 6·7
6, 1845.	Toronto					6 07·9	46·8	597·8	33·1	4 50·9	46·8	599·5	33·0						
8, 1845.	Toronto	575·0	40·3			10 27·9	55·6	582·0	40·9	7 53·9	56·7	581·0	41·0	5·0870(s.)	310	55·4	592·1	36·7	− 7·3
8, 1845.	Toronto					6 06·9	57·9	578·1	40·1	4 50·0	57·4	578·4	40·1	4·2067	316	59 3	598·1	38·0	− 7·3
March 4, 1845.	Toronto	575·5	47·4		17	13 42·2	53·0	563·5	46·3	6 47·1	54·5	562·7	46·5	4·3792	370	51·0	565·3	46·8	− 8 0
8, 1845.	Toronto	567·0	51·1			13 34·7	59·9	551·6	53·5	6 43·7	61·7	553·7	53·5	4·3870	294	55·4	562·4	51·5	− 8·0
10, 1845.	Toronto	573·8	46·1			13 36·1	56·2	564·0	46·2	6 44·0	57·1	563·8	46·0	4·3805	376	47·0	566·5	45·3	− 8·0
11, 1845.	Toronto	574·0	47·8			13 34·7	59·1	567·8	49·1	6 43·6	59·0	566·2	49·2	4·3836	312	46·4	566·6	49·3	− 8·0
11, 1845.	Toronto	574·0	47·8		31	10 25·2	61·0	570·4	48·1	4 48·8	63·9	570 0	48·2	4·2000	324	46·8	569·1	49·5	− 8·0

"*Remarks referring to* TABLE XXXIX.

"*Sault St. Mary*, November 4, 1844.—The observations of vibration of No. 31 were accidentally omitted at this station, by the interruption occasioned by the sudden death of one of the voyageurs; the value of X given in the table was deduced from the experiments of deflection, by applying to the observed value of the ratio $\frac{m}{X}$ the known values of m, as given by the observations of September 6, 19, 25 and 29, and October 11, 1844, viz. 0·3; in the general mean it is allowed only half the weight of the complete observations.

"*Fort William*, May 31, 1843, and October 11, 1844.—The reduction of the observed values of X to the mean of the bifilar readings is omitted in the observations of October 11, 1844: the magnetometer was observed, but the connection of the readings did not appear satisfactory.

"*Fort Francis*, June 14, 1843, and September 29, 1844.—The bifilar was not adjusted for the observations of 1844; the value of X by No. 30 in 1844 differs considerably from the mean values by the two other bars, but not to a greater extent than might have been caused by actual changes of the force.

"*Rat Portage*, September 25, 1844.—The unfavourable state of the weather obliged the observations to be made in a dwelling-house, which like all the dwelling-houses in that part of the north of America was constructed of wood, with scarcely any iron whatever; the floor was laid with trenails, and the lock on the door was a wooden one; hence it is considered that the observation is as unexceptionable as if made in the open air: the bifilar was not in adjustment.

"*Winnipeg River*, June 21, 1843.—The value of X is deduced from observations of deflection only, employing the mean values of m given by the complete observations of June 14 and June 30.

"*Upper Fort Garry*, June 30, 1843.—The time of vibration of No. 30 was observed with the weights 5 and 6 attached*, but the second set without the weights could not be taken. The observed value of T'^2 has been multiplied by 0·338, the value of the ratio $\frac{K}{K+K'}$ to obtain the value of T^2, and the square root of the product (4·9748) inserted in table No. XXXVIII.; a few vibrations (22) which were observed as a check, gave a mean value of 4·912.

"*Norway House*, July 14, 1843, and September 6, 1844.—The value of m of bar 31 in 1843, appears too small, being 0·012 less than the mean at the preceding and following stations; the value of X is slightly in excess of the mean of the other two bars (2·178 instead of 2·174), indicating the error to be probably in the experiment of deflection. The observations of 1843 are reduced to the mean of corresponding readings of the bifilar; those of 1844 are reduced to the mean of hourly readings continued for twenty-one hours.

"*York Factory*.—The day of observation at this station, the 26th of July 1843, was one of very considerable magnetic disturbance, and in other respects unfavourable, being windy and showery; the tent which sheltered the bifilar magnetometer was blown down, and the glass tube of the instrument broken, rendering it for the time unserviceable. In consequence of this accident the time of vibration of No. 31 is not reduced to the same value of the horizontal force as the other parts of the experiments; and the mean values of X, by bars 30 and 31, differ to an amount which is very large, when compared with the small value of the horizontal component at the station, *i. e.* $\frac{1}{54}$th its whole amount.

"*Cross Lake*, August 16, 1843.—This was the first occasion on which the bars were vibrated without the stirrup. The bifilar was not in adjustment.

"*Cumberland House*.—The bars were vibrated in 1843, both with and without the stirrup, and the mean horizontal intensity is deduced from all the resulting values of X. The bars were vibrated again in August 1844 with the same mode of suspension, but the experiments of deflection were not made.

"*Carlton House*, August 26, 1844.—The bifilar was not adjusted at this station; and as the experiments of deflection with No. 17 were omitted, the mean value of X is deduced from the observations with bars 30 and 31 only.

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* This was done at several of the stations; but the values of K so obtained have been superseded by the more accurate determination with the brass rings.

"*Edmonton,* August 17, 1844.—The bifilar was adjusted, but the state of the weather prevented the continuance of the readings for so long as twenty-four hours, and the value of X is reduced to the mean of twelve hourly readings only.

"*Athabasca.*—There are three separate determinations at this station with bars 30, 31 and 17, viz. in October 1843, and in March and July 1844; the two former at the beginning and termination of a series of hourly observations of the bifilar, &c., made during the winter of 1843, and the latter after my return to Athabasca, from Mackenzie's river. Three spare bars of various lengths, No. 23, 29 and 20, were also employed in October 1843; but as the results obtained from them were calculated with an assumed temperature coefficient, and their moments of inertia are less accurately known than those of bars 30, 31 and 17, to introduce the values of X given by them into the general mean would only vitiate more accurate results, and they are added for purposes of illustration only; the general mean at the station is the mean by all the observations with bars 30, 31 and 17, except one of bar 17, in which the accuracy of the observed times of vibration appeared doubtful, and which is not included in the Table.

"*Vermilion,* July 12, 1844.—The bifilar was placed in adjustment, and the several parts of the observation are reduced to the mean of the corresponding readings.

"*Dunvegan,* July 23, 1844.—The bifilar was placed in adjustment, and hourly readings taken on the 23rd and 24th of July, the term day of the month. The absolute intensity is reduced to the mean reading of the bifilar on the 23rd, which differs but little from the mean of thirty-two hourly observations.

"*Big Island,* June 20, 1844.—The place of observation was a small fishing-station near the Big Island on Great Slave Lake, and named after it, but not actually upon it. The values of X are deduced from experiments of deflection only, applying the mean values of *m* given by the observations of June 12 and 23. The bifilar was not observed.

"*Fort Simpson,* May 2 and June 12, 1844.—The experiments of May are reduced to the mean reading of the bifilar given by the hourly observations of nine days, from April 27 to May 8. Those of June are reduced to the mean of the readings taken during the experiments; the values of X obtained from the experiments with the spare bars 20 and 23 have not been included in the mean, for the reason given in the remarks on the observations at Athabasca.

"*Fort Good Hope.*—The observation at this, the most northern station of the series, was made at midnight on the 29th and 30th of May, by the soft and beautiful twilight of that season and latitude. The night was calm, and free from any magnetic disturbance. The results are reduced to the mean of twenty hourly observations of the bifilar magnetometer. The value of X by the observation of No. 30, when vibrated in the stirrup, is apparently too small. The suspension thread broke after 100 vibrations had been observed, occupying only $11^m\ 20^s$, being too short a time to give an accurate result in so high a magnetic latitude: in taking the general mean I have allowed it only half the weight of the other results."—J. H. LEFROY.

Determination of the absolute Horizontal Force derived from the times of vibration *of the magnets of the portable unifilar magnetometer in* 1844.

It has been seen by the preceding Table, No. XXXVIII., that there were sixteen stations at which observations of deflection as well as vibration were made with the magnets of the portable unifilar in 1844, and that at three of the stations they were made at two different epochs: there were also twenty-five other stations, visited in the same year, at which the times of vibration only of the magnets are derived; and in respect to these we have in the first instance to derive the magnetic moment of each magnet, at the several periods when the vibrations only were observed, from the deflections at the stations where both processes were completed; and having thus obtained a knowledge of the variations which the magnetism of the bars may have undergone from time to time in the course of the year, we shall be enabled to derive the values of the absolute horizontal force at those stations also, or at least at a great part of them, where the vibrations alone are observed.

The observations, which include the deflections as well as vibrations, have been discussed by Captain LEFROY in the preceding pages; and we are thus furnished with nineteen determinations of the magnetic moment of No. 30, seventeen of No. 31, and fourteen of No. 17, at different times in the course of the year.

The values of m (the magnetic moment) of No. 30 at the stations at which the deflections are observed, were as follows, viz.—

Athabasca, March 2, 1844 . . $m=\cdot4207$.
Fort Simpson, May 2, 1844 . $m=\cdot4166$.
Fort Good Hope, May 29, 1844 $m=\cdot4106$.
Fort Norman, June 2, 1844 . $m=\cdot4091$.
Fort Simpson, June 12, 1844 $m=\cdot4018$.
Fort Resolution, June 24, 1844 $m=\cdot4002$.
Athabasca, July 2, 1844 . . $m=\cdot3988$.
Fort Vermilion, July 11, 1844 $m=\cdot4005$.
Fort Dunvegan, July 24, 1844 $m=\cdot3992$.
Fort Edmonton, Aug. 18, 1844 $m=\cdot3978$.
Carlton House, Aug. 26, 1844 $m=\cdot3965$.
Norway House, Sept. 4, 1844 $m=\cdot3967$.
Fort Alexander, Sept. 20, 1844 $m=\cdot3962$.
Rat Portage, Sept. 25, 1844 . $m=\cdot3964$.
Fort Francis, Sept. 29, 1844 . $m=\cdot3962$.
Fort William, Oct. 10, 1844 . $m=\cdot3962$.
Sault St. Mary, Nov. 5, 1844 . $m=\cdot3940$.
Toronto (with the stirrup), January 1845 . . . . . $m=\cdot3947$.
Toronto (without the stirrup), Jan. 29, 1845 . . . $m=\cdot3931$.

An inspection of these values shows that the magnetism of No. 30 was not constant during the period under consideration, but that a progressive loss took place, which was considerable in amount between March and June, but became much smaller and more regular between June 1844 and January 1845.

The whole of the twenty-five stations at which the times of vibration only were observed, are comprised between Fort Dunvegan on the 24th of July, 1844, and Toronto on January 29, 1845, or during the period when the loss of magnetism of No. 30 was small and tolerably regular; we may therefore assume for this portion of the year the most simple hypothesis of an uniform loss in equal intervals of time, without incurring the risk of any material error. If x be the magnetic moment at Toronto on January 29, 1845, a the interval of time in days between the date of the observations at any anterior station and the 29th of January, and y the change of m corresponding to a single day, each of the stations where observations of deflection were made will furnish an equation of the form,

$$\text{observed value of } m = x + ay\,;$$

and by the method of least squares we shall obtain the most probable values of m on the hypothesis of uniform loss. There are fifteen such equations furnished by No. 30, between June 12, 1844, and January 29, 1845; from these we obtain $m=\cdot 3928$, and $y=\cdot 0000317$. Hence we have m at Toronto on January 29 $=\cdot 3928$; and on any earlier day between June 12, 1844, and January 29, 1845, $m=\cdot 3928+\cdot 0000317a$.

By the experiments with Dr. LAMONT's rings, p. 293, the values of $\pi^2\text{K}$, or the moment of inertia of each of the magnets 30, 31 and 17, multiplied by the square of the ratio of the circumference of a circle to its diameter, were determined as follows, viz.—

No. 30.	21·581.
No. 31.	21·853.
No. 17.	43·272.

The absolute horizontal force at the stations where the observations of vibration only were made, are then deducible from the following expression,

$$\text{X} = \frac{\pi^2\text{K}}{m\text{T}^2},$$

in which T is the time of vibration and m computed as above.

The values of m with magnet No. 31 at the stations where the deflections were observed were as follows:—

Athabasca, March 2, 1844 . .	·3763.	Fort Edmonton, Aug. 18, 1844.	·3507.
Fort Simpson, May 2, 1844 . .	·3721.	Carlton House, Aug. 26, 1844 .	·3499.
Fort Good Hope, May 29, 1844.	·3641.	Norway House, Sept. 4, 1844 .	·3512.
Fort Norman, June 2, 1844 . .	·3616.	Fort Alexander, Sept. 20, 1844 .	·3517.
Fort Simpson, June 12, 1844 .	·3587.	Rat Portage, Sept. 25, 1844 . .	·3515.
Fort Resolution, June 24, 1844.	·3592.	Fort Francis, Sept. 29, 1844 . .	·3506.
Athabasca, July 2, 1844 . . .	·3568.	Fort William, October 10, 1844.	·3522.
Fort Vermilion, July 11, 1844 .	·3592.	Toronto (with stirrup), Feb. 5, 1845.	·3494.
Fort Dunvegan, July 24, 1844 .	·3528.	Toronto (without stirrup), Feb. 5.	·3494.

In this case also the twenty-five stations at which the times of vibration only were observed, were all comprised in the interval between the 24th of July 1844 at Dunvegan, and the 5th of February 1845 at Toronto. The loss of magnetism of No. 31 in this interval appears to have been very small; and to have been progressive, although the evidence on this point is obscured by the occasional irregularities of observation. If we treat the observed values between Dunvegan and Toronto in the manner already described in discussing the observations with No. 30, we obtain ·3495 as the value of m at Toronto on the 5th of February 1845, and ·3495+·000012a as its value on any anterior day in that interval.

The values of m with No. 17, derived from the deflections, are as follows:—

Fort Simpson, May 2, 1844 . .	·6858.
Fort Simpson, June 12, 1844 .	·6738.
Fort Resolution, June 24, 1844.	·6707.
Athabasca, July 2, 1844 . . .	·6691.
Fort Vermilion, July 11, 1844 .	·6678.
Fort Dunvegan, July 24, 1844 .	·6727.
Fort Edmonton, Aug. 18, 1844.	·6702.
Norway House, Sept. 4, 1844 .	·6441.
Fort Alexander, Sept. 20, 1844.	·6414.
Rat Portage, Sept. 25, 1844 . .	·6423.
Fort Francis, Sept. 29, 1844. .	·6401.
Fort William, October 10, 1844.	·6405.
Sault St. Mary, Nov. 5, 1845 .	·6393.
Toronto, March 8, 1845 . . .	·6368.

A cursory examination of these values suffices to show, that between September 4, 1844, at Norway House, and March 8, 1845, at Toronto, a small and progressive loss of magnetism was sustained; but that between the observations at Fort Edmonton on the 18th of August, and those at Norway House on the 4th of September, an irregular and very considerable loss occurred. A more careful examination of the times of vibration of this magnet, in comparison with those of No. 30 and 31, show that the period at which this loss took place was, after the observations at Devil's Drum Island on September 1, and before those at Norway House on the 4th of the same month. The stations therefore at which the observations of deflection were made with this magnet may be divided into two series; one antecedent to the loss thus sustained, and the other subsequent to it. For the latter series, viz. between Norway House on the 4th of September and Toronto in February 1845, the most probable values of m have been obtained by the method of least squares in the manner already described; which gives for m at Toronto, on the 8th of March 1845, =·6363, and on anterior days ·6363+·000032a. But we have still to provide for the observations of vibration made in July and August, and for this period the arithmetical mean of the observed values of m between June 24 at Fort Resolution, and August 18 at Fort Edmonton, viz. ·6700, is perhaps the least exceptionable value that can be taken; the irregularities of the observed values during the period would scarcely justify a more precise deduction.

When the values of m, resulting from the observations made with a magnet at several stations of a survey, give reason to infer that its magnetism has remained constant, it is obviously preferable to employ at each station a mean value of m derived from the whole body of the observations, as irregularities of individual determinations afford a mutual compensation. When the loss of magnetism during the whole or a part of the survey has been small and progressive, a probable value of m, computed for the period of the loss in the manner described, may continue to be preferable at the stations where the individual values were observed. For other portions of a survey where the observed discrepancies are considerable, and where they present an alternation of increasing and decreasing values, an arithmetical mean may furnish the most probable value: but when the observed values at successive stations have varied to an amount which considerably exceeds what may reasonably be ascribed to observation error,—and whilst they manifest a progressive loss, afford no very decided indication of its regularity in correspondence with intervals of time,—a satisfactory combination may not be possible, and it may be safer to employ the individual values furnished at each station of observation. Thus the arithmetical mean of the four values obtained with No. 31, from June 12 at Fort Simpson to July 11 at Fort Vermilion, appears preferable to the values themselves, or to any other deduction that might be made for that period; and in the case of No. 17, the values observed on May 2 and June 12 are probably preferable to any others which could be assigned for the respective epochs, but their differences are too great to permit a value to be derived from them for any intermediate or an earlier period.

The following Table contains the times of vibration of the three magnets, Nos. 30, 31 and 17, at the whole of the stations in 1844, with the values of m either observed or deduced in the manner which has been described, and the absolute horizontal force computed by $X = \frac{\pi^2 K}{m T^2}$.

Table XL.

Station.	Date.	Magnet.	Time of vibration. s	Magnetic moment.	Horizontal force in absolute measure.	
Athabasca	March 1844.	30	5·0328	·4207	2·025	2·018
		31	5·3740	·3763	2·011	
		17	5·5204	*	*	
Fort Simpson..........	May 2, 1844.	30	5·1393	·4166	1·961	1·961
		31	5·4691	·3721	1·963	
		17	5·6751	·6858	1·959	
Fort Good Hope	29, 1844.	30	5·6013	·4106	1·67	1·678
		31	5·9763	·3641	1·68	
		17	6·1109	*	*	
Fort Norman..........	June 2, 1844.	30	5·4832.	·4091	1·755	1·763
		31	5·4803	·3616	1·772	
		17	5·9717	*	*	
Fort Simpson..........	12, 1844.	30	5·2323	·4018	1·962	1·954
		31	5·5993	·3587	1·943	
		17	5·7305	·6738	1·956	
Fort Resolution........	24, 1844.	30	5·5320	·3998	1·767	1·767
		31	5·8714	·3585	1·768	
		17	6·0479	·6700	1·766	
Athabasca............	July 2, 1844.	30	5·1507	·3995	2·036	2·036
		31	5·4725	·3585	2·035	
		17	5·6326	·6700	2·036	
Fort Vermilion	11, 1844.	30	4·9000	·3992	2·251	2·250
		31	5·1890	·3585	2·264	
		17	5·3771	·6700	2·234	

TABLE XL. (Continued.)

Station.	Date.	Magnet.	Time of vibration.	Magnetic moment.	Horizontal force in absolute measure.	
			s			
Fort Dunvegan	July 24, 1844.	30	4·4557	·3988	2·726	2·732
		31	4·7671	·3519	2·733	
		17	4·8589	·6700	2·736	
Lesser Slave Lake......	Aug. 5, 1844.	30	4·4449	·3985	2·744	2·731
		31	4·7706	·3517	2·730	
		17	4·8741	·6700	2·718	
Fort Edmonton	18, 1844.	30	4·2948	·3989	2·940	2·942
		31	4·5939	·3515	2·946	
		17	4·6876	·6700	2 939	
Saskatchawan	20, 1844.	30	4·3747	·3979	2·834	2·829
		31	4·6908	·3515	2·826	
		17	4·7792	·6700	2·828	
Saskatchawan	21, 1844.	30	4·4348	·3979	2·758	2·746
		31	4·7706	·3515	2·732	
		17	4·8472	·6700	2·749	
Fort Pitt	22, 1844.	30	4·4167	·3979	2·781	2·778
		31	4·7334	·3515	2·775	
		17	4·8223	·6700	2·777	
Saskatchawan	23, 1844.	30	4·3646	·3978	2·848	2·847
		31	4·6798	·3515	2·839	
		17	4·7562	·6700	2·855	
Saskatchawan	24, 1844.	30	4·3520	·3978	2·865	2·865
		31	4·6534	·3515	2·871	
		17	4·7525	·6700	2·860	
Carlton House	26, 1844.	30	4·4542	·3977	2·735	2·737
		31	4·7654	·3515	2·738	
		17	4·8565	·6700	2·738	
Saskatchawan	27, 1844.	30	4·5560	·3977	2·614	2·615
		31	4·8791	·3515	2·612	
		17	4·9668	·6700	2·618	
Cumberland House	29, 1844.	30	4·7775	·3976	2·378	2·376
		31	5·1080	·3515	2·383	
		17	5·2235	·6700	2·367	
Near the Pas	31, 1844.	30	4·7705	·3975	2·385	2·386
		31	5·1090	·3514	2·383	
		17	5·1978	·6700	2·391	
Devil's Drum Island	Sept. 1, 1844.	30	4·7485	·3975	2·408	2·399
		31	5·0968	·3514	2·394	
		17	5·1934	·6700	2·395	
Grand Rapid	Sept. 2, 1844.	30	4·8097	·3975	2·347	2·343
		31	5·1558	·3514	2·340	
		17	5·3157	*	....	
Norway House	4, 1844.	30	5·0058	·3974	2·166	2·171
		31	5·3569	·3513	2·168	
		17	5·5516	·6441	2·180	
Lake Winnipeg	14, 1844.	30	4·7613	·3971	2·397	2·398
		31	5·2045	·3512	2·397	
		17	5·2997	·6419	2·400	
Lake Winnipeg	16, 1844.	30	4·4437	·3971	2·754	2·763
		31	4·7457	·3512	2·763	
		17	4 9326	·6418	2·771	
Lake Winnipeg	17, 1844.	30	4·4662	·3970	2·725	2·721
		31	4·7866	·3512	2·716	
		17	4·9768	·6418	2·722	
Lake Winnipeg	18, 1844.	30	4·5414	·3970	2·636	2·639
		31	4·8576	·3512	2·637	
		17	5·0498	·6418	2·644	

* Value uncertain.

TABLE XL. (Continued.)

Station.	Date.	Magnet.	Time of vibration.	Magnetic moment.	Horizontal force in absolute measure.	
			s			
Fort Alexander	Sept. 20, 1844.	30	4·4898	·3970	2·697	2·698
		31	4·7943	·3511	2·708	
		17	5·0090	·6417	2·688	
Rat Portage	25, 1844.	30	4·3592	·3969	2·864	2·876
		31	4·6466	·3511	2·883	
		17	4·8392	·6415	2·880	
Fort Francis	29, 1844.	30	4·2395	·3967	3·027	3·040
		31	4·5242	·3510	3·042	
		17	4·7110	·6414	3·040	
Portage des 2 Rivières	Oct. 4, 1844.	30	4·3170	·3965	2·921	2·930
		31	4·6034	·3510	2·938	
		17	4·7976	·6413	2·932	
Prairie Portage	7, 1844.	30	4·3838	·3964	2·834	2·844
		31	4·6720	·3510	2·853	
		17	4·8705	·6412	2·845	
Chien Portage	9, 1844.	30	4·3888	·3964	2·826	2·836
		31	4·6840	·3510	2·838	
		17	4·8717	·6411	2·844	
Fort William	10, 1844.	30	4·3474	·3963	2·882	2·881
		31	4·6387	·3509	2·894	
		17	4·8517	·6411	2·868	
Lake Superior	14, 1844.	30	4·1192	·3962	3·211	3·213
		31	4·3988	·3509	3·219	
		17	4·5875	·6409	3·208	
Fort Pic	17, 1844.	30	4·4726	·3961	2·724	2·725
		31	4·7741	·3508	2·733	
		17	4·9833	·6408	2·719	
White River	21, 1844.	30	4·4104	·3960	2·804	2·803
		31	4·7096	·3508	2·809	
		17	4·9150	·6407	2·796	
Fort Michipicoton	30, 1844.	30	4·3598	·3957	2·869	2·870
		31	4·6507	·3507	2·881	
		17	4·8606	·6404	2·860	
Gargantua	31, 1844.	30	4·1408	·3956	3·182	3·190
		31	4·4156	·3507	3·196	
		17	4·6015	·6404	3·191	
Sault St. Mary	Nov. 5, 1844	30	4·2527	·3954	3·018	3·026
		31	not observed.	....	....	
		17	4·7196	·6403	3·034	
La Cloche	8, 1844.	30	4·2058	·3953	3·087	3·108
		31	4·4774	·3506	3·109	
		17	4·6495	·6401	3·127	
Penetanguishene	15, 1844.	30	4·0551	·3951	3·323	3·326
		31	4·3324	·3505	3·322	
		17	4·5047	·6397	3·333	
Toronto	Jan. 29, 1845.	30	3·9463	·3928	3·528	3·537
	Feb. 5, 1845.	31	4·2041	·3495	3·538	
	Mar. 8, 1845.	17	4·3858	·6363	3·536	

Determination of the absolute Horizontal Force derived from the times of vibration *of the magnets of the portable unifilar magnetometer in* 1843.

Besides the ten stations at which observations both of deflection and of vibration were made with Nos. 30 and 31 in 1843, which have been discussed in pp. 289–302, there were also thirteen stations at which the times of vibration only were observed, unaccompanied by observations of deflection: these stations were all comprised between Cumberland House on the 22nd of August and Athabasca on the 13th of October. The deflections observed at Cross Lake and Cumberland House on the 16th and 22nd of August, and at Athabasca on the 13th of October, indicate that the magnetic moment of both magnets sustained a considerable diminution in the interval; and from the only intermediate determination, made at Isle à la Crosse on the 9th of September, we may infer that the greater part at least, if not the whole of the loss, occurred in both magnets between August 23 and September 9. For the second portion of the interval therefore, or from September 9 to October 23, the arithmetical mean of the determinations at Isle à la Crosse and at Athabasca have been taken for the values of m, viz. ·4138 for No. 30, and ·3841 for No. 31. In regard to the previous interval, or that comprised between August 22 and September 9, the observations at Cumberland House and at Isle à la Crosse manifest that a very considerable change took place in the magnetic moment of both bars, but as intermediate observations of deflection are wholly wanting we have no direct evidence of the particular time when it occurred. A careful examination and comparison of the times of vibration at the intermediate stations makes it probable that the greater portion at least of the loss occurred in No. 31 between Cumberland House and Beaver Lake, and in No. 30 between Beaver Lake and the Portage des Epinettes; but as there is necessarily much uncertainty involved in any conclusion on this point, it has appeared the safest course to record the times of vibration at the stations between Cumberland House and Isle à la Crosse without an attempt to deduce the horizontal force from them.

The times of vibration of No. 17 were also observed at the stations between Cumberland House and Athabasca, but no deflection experiments were made with it before the arrival at Athabasca; it appears by the observations of vibration that this bar unquestionably lost magnetism in the interval, but as there is no independent evidence to show at what particular time the loss took place, or whether it was of a sudden or of a progressive character, the times of vibration with this magnet have also been recorded, but no conclusion has been drawn from them in regard to the values of the horizontal force at any earlier station than at Athabasca.

TABLE XLI.

Absolute Horizontal Force deduced from the times of vibration of Nos. 30 and 31 in 1843.

Station.	Date.	Magnet.	Time of vibration.	Magnetic moment.	Horizontal force in absolute measure.	
			s.			
Isle à la Crosse	Sept. 9.	30	4·6589	·4138	2·403	2·394
		31	4·8838	·3841	2·386	
Buffaloe Lake..........	13.	30	4·7694	·4138	2·283	2·278
		31	4·9986	·3841	2·273	
River de la Loche......	14.	30	4·7101	·4138	2·341	2·336
		31	4·9345	·3841	2·332	
Portage de la Loche	16.	30	4·7725	·4138	2·280	2·278
		31	4·9968	·3841	2·275	
Clearwater River	19.	30	4·7822	·4138	2·271	2·262
		31	5·0201	·3841	2·253	
Pierre au Calumet......	20.	30	4·8867	·4138	2·175	2·172
		31	5·1162	·3841	2·170	
Pointe Brulée..........	21.	30	5·0054	·4138	2·073	2·067
		31	5·2482	·3841	2·062	
Athabasca	Oct. 13.	30	5·0514	·4138	2·035	2·036
		31	5·2816	·3841	2·036	

TABLE XLII.

Times of Vibration of Nos. 30, 31 and 17, between August 22 and October 13, recorded but not employed.

Station.	1843.	No. 30.	No. 31.	No. 17.	Station.	Date.	No. 17.
Cumberland House	Aug. 22.	....	....	5·126	Isle à la Crosse	Sept. 9.	5·116
Beaver Lake	26.	4·667	4·945	5·205	Buffaloe Lake..........	13.	5·236
Portage des Epinettes ..	28.	4·689	5·007	5·272	River de la Loche......	14.	5·169
Frog Portage..........	29.	4·786	5·049	5·318	Portage de la Loche	16.	5·231
Great Devil Portage	Sept. 1.	4·765	4·937	5·286	Clearwater River	19.	5·253
Pine Portage	3.	4·786	5·011	....	Pierre au Calumet......	20.	5·364
Snake Rapid	4.	4·760	4·983	5·231	Pointe Brulée..........	21.	5·493
Portage Sonnante	7.	4·644	4·879	5·097			

Collecting then in one view the results obtained by Lieut. LEFROY with the magnets of the German and unifilar magnetometers, and employing the Inclinations observed at the stations which will be found in the general table at the close of § 12, we have the values of the horizontal component, and of the total Force, severally as follows:—*a.* signifies by the German magnetometer; *b.* by the unifilar, where both deflections and vibrations have been observed; and *c.* when the times of vibration only of the magnets of the unifilar were observed.

TABLE XLIII.

Station.	Date.	Horizontal component.	Mean horizontal component.	Total force in absolute measure.	Remarks.
Quebec	1842.	3·040 *a.*	3·040	13·78	
Montreal	1842.	3·064 *a.*	3·064	13·78	
New York	1842.	4·008 *a.*	4·008	13·49	Lunatic Asylum.
Cambridge	1842.	3·665 *a.*	3·665	13·55	
Philadelphia	1842.	4·176 *a.*	4·176	13·50	Observed by Lieut. YOUNGHUSBAND, R.A.
Chicago	1842.	4·106 *a.*	4·106	13·77	
Fort William	1843.	2·869 *b.*	2·875	13·91	
Fort William	1844.	2·881 *b.*			
Fort Francis	1843.	3·048 *b.*	3·044	14·18	
Fort Francis	1844.	3·040 *b.*			
Upper Fort Garry	1843.	2·849 *b.*	2·849	14·05	
Norway House	1843.	2·176 *b.*	2·173	14·18	
Norway House	1844.	2·171 *b.*			
York Factory	1843.	1·523 *b.*	1·523	14·07	
Cross Lake	1843.	2·352 *b.*	2·352	14·21	
Cumberland House	1843.	2·341 *b.*	2·358	14·12	
Cumberland House	1844.	2·376 *b.*			
Isle à la Crosse	1843.	2·394 *c.*	2·394	14·01	
Buffaloe Lake	1843.	2·278 *c.*	2·278	13·97	
River de la Loche	1843.	2·336 *c.*	2·336	13·90	
Portage de la Loche	1843.	2·278 *c.*	2·278	13·95	
Clearwater River	1843.	2·262 *c.*	2·262	13·85	
Pierre au Calumet	1843.	2·172 *c.*	2·172	14·33	
Pointe Brulée	1843.	2·067 *c.*	2·067	14·00	
Athabasca	1843.	2·036 *b.*	2·030	13·94	
Athabasca	1844.	2·018 *b.*			
Athabasca	1844.	2·036 *b.*			
Fort Simpson	1844.	1·961 *b.*	1·957	13·84	
Fort Simpson	1844.	1·954 *b.*			
Fort Good Hope	1844.	1·678 *b.*	1·678	13·64	
Fort Norman	1844.	1·763 *b.*	1·763	13·63	
Fort Resolution	1844.	1·767 *b.*	1·767	13·99	
Fort Vermilion	1844.	2·250 *b.*	2·250	14·07	
Fort Dunvegan	1844.	2·732 *b.*	2·732	14·03	
Lesser Slave Lake	1844.	2·731 *b.*	2·731	13·87	
Fort Edmonton	1844.	2·942 *b.*	2·942	14·04	
On the Saskatchawan	1844.	2·829 *c.*	2·829	13·71	
On the Saskatchawan	1844.	2·746 *c.*	2·746	13·84	
Fort Pitt	1844.	2·778 *c.*	2·778	14·15	
On the Saskatchawan	1844.	2·847 *c.*	2·847	14·24	
On the Saskatchawan	1844.	2·865 *c.*	2·865	14·09	
Carlton House	1844.	2·737 *c.*	2·737	13·74	
On the Saskatchawan	1844.	2·615 *c.*	2·615	13·94	
Near the Pas	1844.	2·386 *c.*	2·386	14·32	
Devil's Drum Island	1844.	2·399 *c.*	2·399	13·82	
Grand Rapid	1844.	2·343 *c.*	2·343	14·11	
Lake Winnipeg	1844.	2·365 *c.*	2·398	14·38	
Lake Winnipeg	1844.	2·763 *c.*	2·763	15·37	
Lake Winnipeg	1844.	2·721 *c.*	2·721	14·40	
Lake Winnipeg	1844.	2·639 *c.*	2·639	14·51	

TABLE XLIII. (Continued).

Station.	Date.	Horizontal component.	Mean horizontal component.	Total force in absolute measure.	Remarks.
Fort Alexander	1844.	2·698 *b.*	2·698	14·08	
Rat Portage	1844.	2·876 *b.*	2·876	13·97	
Portage des deux Rivières	1844.	2·930 *c.*	2·930	13·89	
Prairie Portage	1844.	2·844 *c.*	2·844	14·18	
Portage du Chien	1844.	2·836 *c.*	2·836	14·17	
Lake Superior	1844.	3·213 *c.*	3·213	15·89	
Pic Fort..............	1844.	2·725 *c.*	2·725	13·84	
White River	1844.	2·803 *c.*	2·803	14·12	
Fort Michipicoton	1844.	2·870 *c.*	2·870	13·93	
Gargantua	1844.	3·190 *c.*	3·190	15·26	
Sault St. Mary	1844.	3·026 *c.*	3·026	13·98	
La Cloche	1844.	3·108 *c.*	3·108	13·64	
Penetanguishene	1844.	3·326 *c.*	3·326	14·08	
Toronto	1842. 1843.	3·537 *a.*	3·535	13·90	
Toronto	1845.	3·537 *b.*			
Toronto	1845.	3·535 *b.*			
Toronto	1846.	3·533 *b.*			
Woolwich	1846.	3·729 *b.*	3·729	10·39	

Values of the Magnetic Force at Dr. LOCKE's *stations.*

Dr. LOCKE's determinations were of the ratios of the horizontal component of th Force to its value at Cincinnati taken as a base station: it is therefore requisite t establish, in the first instance, the relative values of the magnetic Force at Cincinnat and Toronto on the best evidence that the observations furnish. For this compariso we have—1°. Dr. LOCKE's observations with HANSTEEN's apparatus, at Toronto on th 20th of June, and at Cincinnati on the 4th of July 1844, combined with observation of the Inclination on the same days. The observations of horizontal Force give th ratio ·7784 at Toronto to unity at Cincinnati, and those of Inclination 70° 25'·0 a Cincinnati, and 75° 13'·4 at Toronto. Whence, if we take the total Force at Toront in the arbitrary scale as 1·836, its value at Cincinnati is 1·795.

2°. Dr. LOCKE's determination of the ratios of the horizontal force at New York Cambridge, and Philadelphia, to unity at Cincinnati, with the Inclination at each sta tion, combined with Lieut. LEFROY's determination of the ratios of the horizonta force at the same three stations to the force at Toronto, all which were observe with the magnets of the German transportable magnetometer. The place of obser vation at New York, Cambridge and Philadelphia, was the same with both observers viz. the Lunatic Asylum at Manhattanville near New York, and the magnetic obser vatories at Cambridge and Philadelphia.

The particulars of this comparison are as follows:—

TABLE XLIV.

Station.	Date.	Dr. LOCKE.		Lieut. LEFROY.	Horizontal force deduced at Cincinnati.	Lieut. LEFROY.		Total force at Cincinnati to 1·836 at Toronto.
		Ratio of the horizontal force to 1 at Cincinnati.	Inclination observed at Cincinnati.	Horizontal force observed at the stations in the first column.		Horizontal force observed at Toronto.	Inclination observed at Toronto.	
				(1842.)		(1842.)	(1842.)	
New York	1841.	·8828	70° 26′·2					
	1844.	·8811	70 25·0					
	Mean	·8819	70 25·6	4·008	4·544	3·537	75 16·0	1·791
Cambridge......	1842.	·8040	70 26·2	3·665	4·558	3·537	75 16·0	1·797
Philadelphia ..	1841.	·9175	70 26·2					
	1842.	·9178	70 26·2					
	1844.	·9151	70 25·2					
	Mean	·9168	70 25·8	4·168	4·546	3·537	75 16·0	1·792
							Mean	1·794

Whence we have the total force at Cincinnati=1·794.

3°. Dr. LOCKE's determination of the ratios of the horizontal force at Baltimore, Washington, Princeton, Newhaven, Albany and Sault St. Mary, to unity at Cincinnati, and his observations of the Inclination at those stations, combined with the ratios of the total force to 1·836 at Toronto, determined by Lieut. LEFROY at the same six stations. The particulars of the comparison are as follows:—

TABLE XLV.

Station.	Dates.	Ratio of the horizontal force to 1 at Cincinnati.	Inclination observed at		Total force at Cincinnati to 1·836 at Toronto.	
			the stations in column 1.	Cincinnati.	By observations at the stations in column 1.	Deduced for Cincinnati.
		Dr. LOCKE.	Dr. LOCKE.	Dr. LOCKE.	Lieut. LEFROY.	
Baltimore	1841.	·9370	71° 34′·1	70° 26′·2	1·782	1·796
Washington	1844.	·9483	71 13·4	70 25·0	1·772	1·795
Princeton	1844.	·8833	72 40·4	70 25·0	1·783	1·794
Newhaven	1842.	·8385	73 29·8	70 26·2	1·773	1·794
Albany	1844.	·7876	74 40·2	70 25·0	1·797	1·800
Sault St. Mary	1843.	·6695	77 30·2	70 25·5	1·862	1·796
					Mean	1·796

Whence we have the total force at Cincinnati =1·796. Collecting in one view the results of the three comparisons, we have—

1°. By the direct comparison of the horizontal force at Cincinnati and Toronto, by Dr. LOCKE . . . . 1·795

2°. By three intermediate stations, at which the ratios of the horizontal force were determined by Dr. LOCKE to the force at Cincinnati, and by Lieut. LEFROY to the force at Toronto . . . . 1·794

3°. By six intermediate stations, at which the ratios of the horizontal force were determined to the force at Cincinnati by Dr. LOCKE, and the ratios of the total force to its value at Toronto, by Lieut. LEFROY . . . . . 1·796

The total force at Cincinnati, the base station of Dr. Locke's survey, has therefore been taken =1·795; and the final column in the following Table has been computed accordingly; employing for that purpose the Inclinations observed at the same stations by Dr. Locke, contained in § 12, where also the geographical positions of the stations are given.

Table XLVI.—Values of the Magnetic Force at the stations of Dr. Locke's survey.

Station.	Date.	Ratios of the horizontal force to unity at Cincinnati.	Ratios of the total force.		Station.	Date.	Ratio of the horizontal force to unity at Cincinnati.	Ratios of the total force.	
			To unity at Cincinnati.	To 1·836 at Toronto.				To unity at Cincinnati.	To 1·836 at Toronto.
Cincinnati	......	1·0000	1·0000	1·795	Boston	1842.	·8057	·9845	1·767
Dayton	1838.	·9582	1·0032	1·797	Cambridge	1842.	·8040	·9917	1·774
Dayton	1840.	·9544	·9991		Cambridge ¶	1845.	·7955	·9860	
Springfield	1838.	·9494	·9978	1·791	Bristol	1842.	·8885	·9850	1·768
Urbana	1838.	·9533	1·0122	1·816	Huron	1843.	·8834	1·0123	1·817
Columbus	1838.	·9666	·9967	1·788	Detroit	1843.	·8552	1·0111	1·815
Columbus	1845.	·9644	·9957		Ann Arbor	1843.	·8771	1·0184	1·828
St. Louis	1839.	1·0430	·9973	1·790	Machinac	1843.	·7159	1·0387	1·864
Davenport	1839.	·9385	1·0120	1·816	Sault St. Mary	1843.	·6695	1·0366	1·861
Lostgrove	1839.	·9360	1·0154	1·822	Encampment	1843.	·6959	1·0341	1·856
Wabisepinnecon River	1839.	·9302	1·0206	1·832	Houghton's River	1843.	·6713	1·0266	1·842
Iron Ore Bed	1839.	·9085	1·0302	1·849	Magnetic Inlet	1843.	·6199	1·0652	1·910**
Brown's Settlement	1839.	·9181	1·0129	1 818	Isthmus	1843.	·6298	1·0555	1·895**
Mahoqueta River	1839.	·9034	1·0178	1·818	United States Agency	1843.	·7171	1·0866	1·950**
Farmer's Creek	1839.	·9144	1·0228	1·836	Eagle River	1843.	·6482	1·0367	1·861
White Water River	1839.	·8927	1·0165	1·824	Lapointe	1843.	·7047	1·0445	1·875
Mahoqueta River *	1839.	·8897	1·0093	1·811	Ontanogon River	1843.	·6862	1·0393	1·865
Dubugues Town	1839.	·8805	1·0130	1·818	Isle Royale	1843.	·6464	1·0526	1·889
Little Mahoqueta	1839.	·8813	1·0160	1·823	Cleveland	1843.	·8802	1·0163	1·824
Turkey River	1839.	·8732	1·0091	1·811	Wheeling	1844.	·9167	1·0129	1·813
Prairie du Chien	1839.	·8763	1·0187	1·828	Wheeling	4845.	·9182	1·0070	
Blue Mound	1839.	·8540	1·0174	1·826	Cumberland	1844.	·9390	·9967	1·789
Madison	1839.	·8521	1·0378	1·862	Washington ††	1844.	·9414	1·0026	1·800
Mineral Point	1839.	·8686	1·0137	1·819	Washington ‡‡	1844.	·9483	·9879	1·773
Hamilton	1840.	·9383	1·0035	1·801	Georgetown	1844.	·9413	·9849	1·768
Piqua	1840.	·9461	1·0026	1·799	Mount Vernon	1844.	·9685	·9933	1·782
Lebanon	1840.	·9720	1·0011	1·797	Princeton	1844.	·8833	·9940	1·783
Mason	1840.	·9770	·9989	1·793	Princeton §§	1844.	·8815	·9927	1·781
Williamstown	1840.	1·0122	·9932	1·783	Princeton ‖‖	1844.	·8905	·9973	1·790
Lexington	1840.	1·0120	·9854	1·769	New Brunswick	1844.	·8814	·9946	1·785
Clay's Ferry	1840.	1·0203	·9893	1·775	Powkeepsie	1844.	·8808	·9959	1·787
Frankfort	1840.	1·0151	·9887	1·774	Opposite Powkeepsie	1844.	·8197	1·0094	1·811
Louisville	1840.	1·0234	·9965	1·788	Greenbush	1844.	·7867	·9978	1·791
Mount Vernon	1840.	1·0646	·9913	1·779	Albany	1844.	·7876	·9985	1·792
New Harmony	1840.	1·0581	·9908	1·778	Utica	1844.	·7876	1·0078	1·809
Princeton	1840.	1·0447	·9923	1·781	Rochester	1844.	·7948	1·0061	1·806
Vincennes	1840.	1·0260	·9985	1·792	Lockport	1844.	·7913	1·0073	1·808
Paoli	1840.	1·0313	·9880	1·775	Buffaloe	1844.	·8054	1·0170	1·825
Philadelphia	1841.	·9174	·9943	1·784	Ashtabula	1844.	·8600	1·0335	1·855
Philadelphia	1842.	·9178	·9955		Warren	1844.	·8806	1·0056	1·805
Philadelphia	1844.	·9151	·9918		Wellsville	1844.	·8927	·9999	1·794
Pittsburg	1841.	·8915	1·0052	1·803	Toronto ¶¶	1844.	·7784	1·0229	1·836
Pittsburg	1842.	·8907	1·0041		Near Toronto***	1844.	·7789	1·0220	1·835
Pittsburg	1845.	·8869	1·0034		Marietta	1845.	·9566	1·0025	1·800
Chambersburgh	1842.	·9216	·9964	1·788	Near Marietta	1845.	·9507	·9999	1·795
Mount St. Mary's	1842.	·9319	·9977	1·790	Allegheny Summit	1845.	·9026	1·0025	1·800
Baltimore	1841.	·9370	·9935	1·784	Portland	1845.	·7535	·9897	1·776
Baltimore †	1841.	·9319	·9914	1·779	Locke's Mills	1845.	·7265	·9950	1·786
Trenton	1841.	·9246	·9978	1·790	Bethel	1845.	·7274	·9965	1·789
Newark	1841.	·8785	·9957	1·784	Goreham	1845.	·7442	·9993	1·794
Newark	1844.	·8756	·9925		Mount Washington	1845.	·7287	·9915	1·780
New York ‡	1841.	·8835	·9943	1·785	Near Mount Washington	1845.	·7334	·9914	1·780
New York ‡	1844.	·8817	·9944		Oxford	1845.	·9732	1·0056	1·805
New York §	1841.	·8828	·9918	1·781	Richmond	1845.	·9574	1·0020	1·799
New York §	1844.	·8811	·9924		St. Mary's	1845.	·9255	1·0056	1·805
New York ‖	1841.	·9003	·9942	1·784	Carrolton	1845.	·9662	1·0024	1·800
Newhaven	1842.	·8385	·9884	1·774					

* North Branch. † St. Mary's College. ‡ Columbia College.
§ Lunatic Asylum, Manhattanville. ‖ New Asylum. ¶ Mr. Bond's Magnetic Observatory.
** At these four stations, which are all within one mile of each other, considerable local disturbance obviously exists. †† Magnetic Observatory. ‡‡ Grounds of the Capitol, mean of the east and west sides.
§§ Pott's Wood. ‖‖ Rock Hills (trap). ¶¶ Magnetic Observatory. *** In the woods.

Values of the Magnetic Force at Mr. RENWICK's *Stations.*

Mr. RENWICK's observations consisted partly of determinations of the absolute horizontal force with a portable unifilar magnetometer, and partly of determinations of its ratios, by means of the times of vibrations of the magnet of the unifilar, of which the magnetism is assumed to have been constant. The absolute values of the total force are derived from the horizontal component obtained by both classes of observations, by applying the Inclinations observed at the same stations, which will be found in the General Table of Inclinations in the sequel, where also the geographical positions of Mr. RENWICK's stations are given. The particulars of the magnetic determinations will be contained in the official publication of the United States Government: the results now communicated have been computed by Mr. RENWICK.

TABLE XLVII.

Results of the Observations on the Magnetic Force made by Mr. RENWICK in 1844.

Station.	Absolute horizontal force.	Absolute total force.	Remarks.
Stonington	3·7479	13·133	Vibrations and deflections.
Bridgeport	3·7380	13·050	
Greenport	3·8501	13·142	
Saybrook	3·5636	13·388	
New York (Columbia College)	4·1317	13·883	Vibrations only.
New York (Old Lunatic Asylum)	4·0913	13·849	
Sandy Hook	4·1270	13·824	
Yale College	3·8758	13·514	
Stamford	3·9429	13·512	
Oyster Bay	3·9526	13·506	

The determinations of the magnetic force which have been discussed in the preceding pages, are collected in one view in the following General Table, No. XLVIII.; which exhibits the names of the stations, their geographical positions, the observers, and the intensities of the Force; the latter are placed in separate columns according to the nature of the determination in each case, the relative values of the total Force being placed in the one column, and the absolute values of the horizontal component in another; the former are expressed in the arbitrary scale, and are dependent on 1·836 as the force at Toronto; the latter are expressed in British units. A final column is added for the purpose of showing the total Force in absolute measure corresponding to the determinations in the two preceding columns: when the deduction is from the horizontal component, the values in the final column are the horizontal force multiplied by the secant of the observed Inclination; when from the ratios of the total Force, they have been computed by multiplying the respective ratios by $\frac{13·896}{1·836}$. The number of separate results in the Table is 289, of which 222 are relative, and 67 are absolute determinations. The number of stations at which the force has been obtained by these observations is 234. Seventeen of the results at fifteen stations present discordances much exceeding the ordinary limits; in most of these cases similar discrepancies occur in the observations of the Inclination also, whence it may be inferred that they are occasioned by station-error. Setting aside these seventeen results, there remain 272 independent determinations at 219 stations distributed over a portion of the earth's surface, extending in latitude above twenty-eight degrees, and in longitude above fifty degrees.

At thirty-five of Captain Lefroy's stations, results were obtained both by the magnets of the unifilar magnetometer, and by the statical needles. Omitting Pierre au Calumet, where much local disturbance prevailed, there are thirty-four stations at which the values of the total Force in absolute measure derived from the two methods admit of being compared; when this is done it is found that the values obtained by the horizontal method are in excess at fifteen stations, and in defect at an equal number, the results being identical at the remaining four stations. The sum of the differences in excess is 1·95, and in defect 1·22; the difference of these two numbers divided by 34 (the number of stations), gives ·0215 as the average excess of the absolute determinations, or about ·0015 of the whole force. As the two methods of experimenting are perfectly independent of each other, having no single element in common, such an agreement is a very satisfactory confirmation of the general merits of both, and testifies, far more than any verbal expressions, in praise of the unremitting care with which the observations were conducted and executed. The sum of the differences in excess and defect, taken without reference to signs, is 3·17, which divided by 34 gives an average difference at each station of 0·09 between the two methods. As in all probability the differences which appear in the results of the two methods in such very high magnetic latitudes are chiefly attributable to observation-error in the *Inclinations*, of which the secants are employed in the deduction of the total Force from the horizontal components, it may be proper to notice that an error of 0·09 in the total Force is equivalent, when the Inclination is 80°, to an observation-error of less than 4′ in the Inclination: and when all the circumstances are considered under which the observations of Inclination were made, an average error of 4′ in determinations, which rarely admitted of confirmation on a second day, will by no means appear an extraordinary amount.

As a considerable portion of the statical determinations of the Force, and of the observations of Inclination, were entrusted to Bombardier Henry, I may take this occasion to insert, as I have great pleasure in doing, the following extract from a communication from Captain Lefroy:—"During the twenty months which I passed in the Hudson's Bay Territories, Bombardier Henry was my only English assistant: his excellent conduct and cheerful endurance at times of considerable inconvenience and hardships, did as much credit to his character as a non-commissioned officer of artillery, as the interest with which he devoted himself to the observations entrusted to him did to his zeal and intelligence."

TABLE XLVIII. General Table of the Observations of the Magnetic Force.

Station.	Lat.	Long.	Observer.	Magnetic force.		
				Relative scale. Toronto = 1·836.	In absolute measure.	
					Horizontal.	Total.
	Between the latitudes of 38° and 40°.					
St. Louis	38° 38′	269° 56′	LOCKE.	1·790	....	13·55
New Harmony	38 11	272 12	LOCKE.	1·778	....	13·46
Mount Vernon	37 59	272 13	LOCKE.	1·779	....	13·47
Princeton	38 23	272 30	LOCKE.	1·781	....	13·48
Vincennes	38 43	272 35	LOCKE.	1·792	....	13·56
Paoli	38 05	273 25	LOCKE.	1·775	....	13·44
Louisville	38 03	274 30	LOCKE.	1·788	....	13·53
Richmond	39 49	275 13	LOCKE.	1·799	....	13·61
Frankfort	38 14	275 20	LOCKE.	1·774	....	13·43
Oxford	39 30	275 22	LOCKE.	1·805	....	13·66
Hamilton	39 23	275 28	LOCKE.	1·801	....	13·63
Williamstown	38 36	275 38	LOCKE.	1·783	....	13·50
Cincinnati	39 06	275 38	LOCKE.	1·795	....	13·59
Dayton	39 44	275 43	LOCKE.	1·797	....	13·60
Clay's Ferry	37 54	275 42	LOCKE.	1·775	....	13·43
Lexington	38 06	275 42	LOCKE.	1·769	....	13·38
Mason	39 22	275 47	LOCKE.	1·793	....	13·57
Carrolton	39 38	275 51	LOCKE.	1·800	....	13·62
Lebanon	39 26	275 54	LOCKE.	1·797	....	13·60
Springfield	39 54	276 09	LOCKE.	1·791	....	13·55
Columbus	39 57	276 57	LOCKE.	1·788	....	13·53
Marietta Island	39 25	278 32	LOCKE.	1·800	....	13·62
Near Marietta Island	?	?	LOCKE.	1·795	....	13·58
Chambersburg	39 55	282 20	LOCKE.	1·788	....	13·53
Mount St. Mary's	39 41	282 42	LOCKE.	1·790	....	13·55
Mount Vernon	38 41	282 53	LOCKE.	1·782	....	13·49
Georgetown	38 53	282 57	LOCKE.	1·768	....	13·38
Washington	38 53	282 59	LOCKE.	1·773*	....	13·42
Washington	38 53	282 59	LEFROY.	1·772*	....	13·41
Washington	38 54	282 59	LOCKE.	1·800†	....	13·62
Washington	38 54	282 59	LEFROY.	1·798†	....	13·61
Baltimore	39 17	283 22	LOCKE.	1·779	....	13·47
Baltimore	39 17	283 23	LOCKE.	1·784	....	13·50
Baltimore	39 17	283 23	LEFROY.	1·782	....	13·49
Philadelphia	39 58	284 50	LOCKE.	1·784‡	....	13·50
Philadelphia	39 58	284 50	LEFROY.	1·793‡	....	13·57
Philadelphia	39 58	284 50	LEFROY.	....	4·176‡	13·50
	Between the latitudes of 40° and 45°.					
Prairie du Chien	43 01	268 51	LOCKE.	1·828	....	13·83
Brown's Settlement	42 02	268 54	LOCKE.	1·818	....	13·76
Mahoqueta River	42 14	269 03	LOCKE.	1·818	....	13·76
North branch of ditto	42 23	269 08	LOCKE.	1·811	....	13·71
Turkey River	42 42	269 12	LOCKE.	1·811	....	13·71
Iron Ore Bed	41 55	269 20	LOCKE.	1·849§	....	13·99
White Water River	42 18	269 22	LOCKE.	1·824	....	13·80

* Grounds of the Capitol.

† Magnetic Observatory. The Inclinations observed at the Magnetic Observatory and in the grounds of the Capitol, differ also about one-third of a degree; the results at the observatory are omitted in the map.

‡ Magnetic Observatory.

§ Local influence; omitted in the map.

TABLE XLVIII. (Continued.)

Station.	Lat.	Long.	Observer.	Magnetic force.		
				Relative scale. Toronto = 1·836.	In absolute measure. Horizontal.	Total.
	Between the latitudes of 40° and 45° (continued).					
Little Mahoqueta River	42° 31′	269° 29′	LOCKE.	1·823	....	13·80
Davenport	41 30	269 34	LOCKE.	1·818	....	13·76
Wabisepinnecon River	41 44	269 37	LOCKE.	1·832	....	13·86
Dubuques Town	42 29	269 37	LOCKE.	1·818	....	13·76
Farmer's Creek	42 13	269 37	LOCKE.	1·836	....	13·90
Lostgrove	41 39	269 51	LOCKE.	1·822	....	13·79
Mineral Point	42 50	270 06	LOCKE.	1·819	....	13·76
Blue Mound	43 01	270 22	LOCKE.	1·826	....	13·82
Madison	43 04	270 54	LOCKE.	1·862‡	....	14·09
Chicago	41 53	272 16	YOUNGHUSBAND.	1·823	....	13·80
Chicago	41 53	272 16	YOUNGHUSBAND.	....	4·106	13·77
St. Mary's	40 32	275 41	LOCKE.	1·805	....	13·66
Piqua	40 06	275 47	LOCKE.	1·799	....	13·61
Urbana	40 05	276 12	LOCKE.	1·816	....	13·74
Ann Arbor	42 18	276 15	LOCKE.	1·828	....	13·84
Amherstburg	42 06	276 47	LEFROY.	1·822	....	13·79
Detroit	42 25	277 04	LEFROY.	1·814	....	13·72
Detroit	42 25	277 04	LOCKE.	1·815	....	13·73
Detroit	42 25	277 04	YOUNGHUSBAND.	1·826	....	13·82
Port Sarnia	42 58	277 26	LEFROY.	1·825	....	13·81
Huron	41 26	277 33	LOCKE.	1·817	....	13·75
Goderich	43 45	278 03	LEFROY.	1·828	....	13·84
Cleveland	41 30	278 18	LOCKE.	1·824	....	13·80
Cleveland	41 30	278 18	YOUNGHUSBAND.	1·807	....	13·67
Ashtabula	41 52	279 08	LOCKE.	1·855‡	....	14·04
Warren	41 16	279 11	LOCKE.	1·805	....	13·66
Wheeling	40 08	279 13	LOCKE.	1·813	....	13·72
Wellsville	40 38	279 16	LOCKE.	1·794	....	13·58
Pittsburg	40 32	279 58	LOCKE.	1·803	....	13·65
Penetanguishene	44 49	279 59	LEFROY.	....	3·326	14·08
Toronto	43 39	280 39	LEFROY.	1·836	....	13·90
Toronto	43 39	280 39	LOCKE.	1·836	....	13·90
Toronto	43 39	280 39	LEFROY.	....	3·535	13·90
Near Toronto	43 39	280 41	LOCKE.	1·835	....	13·89
Niagara	43 05	280 51	LEFROY.	1·822	....	13·79
Buffaloe	42 53	281 06	LEFROY.	1·814	....	13·73
Buffaloe	42 53	281 06	LOCKE.	1·825	....	13·81
Lockport	43 11	281 14	LOCKE.	1·808	....	13·68
Allegheny Summit	40 27	281 50	LOCKE.	1·800	....	13·62
Rochester	43 08	282 09	LOCKE.	1·806	....	13·67
Cumberland	40 13	283 10	LOCKE.	1·789	....	13·54
Brockville	44 35	284 15	YOUNGHUSBAND.	1·812	....	13·71
Utica	43 07	284 47	LOCKE.	1·809	....	13·69
Bristol	40 06	285 13	LOCKE.	1·768	...	13·38
Trenton	40 13	285 20	LOCKE.	1·790	....	13·55
Princeton	40 22	285 20	LOCKE.	1·783	....	13·50
Princeton	40 22	285 20	LEFROY.	1·783	....	13·50
Princeton*	40 22	285 20	LOCKE.	1·781	....	13·48
Princeton†	40 22	285 20	LOCKE.	1·790	....	13·55
New Brunswick	40 30	285 25	LOCKE.	1·785	....	13·51
Newark	40 43	285 50	LOCKE.	1·784	....	13·50

* Pott's Woods. † Rock Hills (trap). ‡ Apparent local influence; omitted in the map.

Table XLVIII. (Continued.)

Station.	Lat.	Long.	Observer.	Magnetic force. Relative scale. Toronto=1·836.	In absolute measure. Horizontal.	Total.
				Between the latitudes of 40° and 45° (continued).		
	° ′	° ′				
New York*	40 49	285 57	Locke.	1·781	....	13·48
New York*	40 49	285 57	Lefroy.	1·769	....	13·39
Yew York*	40 49	285 57	Lefroy.	....	4·008	13·49
New York*	40 49	285 57	Renwick.	....	4·091	13·85
New York†	40 48	285 58	Locke.	1·784	....	13·50
Sandy Hook	40 27	285 58	Renwick.	....	4·127	13·82
New York‡	40 43	285 59	Locke.	1·785	....	13·51
New York‡	40 43	285 59	Renwick.	....	4·132	13·88
West Point	41 24	285 59	Lefroy.	1·807	....	13·67
Opposite Powkeepsie	41 41	286 04	Locke.	1·811	....	13·71
Powkeepsie	41 41	286 05	Locke.	1·787	....	13·52
Albany	42 39	286 14	Locke.	1·792	....	13·56
Albany	42 39	286 14	Lefroy.	1·797	....	13·60
Greenbush	42 39	286 16	Locke.	1·791	....	13·55
Oyster Bay	40 52	......	Renwick.	....	3·953	13·51
Bridgeport	41 11	286 48	Renwick.	....	3·738	13·05
Newhaven	41 18	287 02	Locke.	1·774	....	13·42
Newhaven	41 18	287 02	Lefroy.	1·773	....	13·42
Newhaven	41 18	287 02	Renwick.	....	3·876	13·51
Greenport	41 06	287 38	Renwick.	....	3·850	13·14
Stamford	41 03	.... .	Renwick.	....	3·943	13·51
Saybrook	41 17	287 39	Renwick.	....	3·564	13·39
Stonington	41 20	288 05	Renwick.	....	3·749	13·13
Mount Washington	44 17	288 31	Locke.	1·780	....	13·47
Providence	41 50	288 35	Lefroy.	1·781	....	13·48
Near Mount Washington.	44 16	288 31	Locke.	1·780	....	13·47
Goreham	44 27	288 47	Locke.	1·794	....	13·58
Cambridge	42 22	288 52	Locke.	1·774	....	13·42
Cambridge	42 22	288 52	Lefroy.	1·777	....	13·45
Cambridge	42 22	288 52	Lefroy.	....	3·665	13·55
Boston	42 22	289 01	Locke.	1·767	....	13·37
Bethel	44 27	289 09	Locke.	1·789	....	13·54
Locke's Mills	44 24	289 16	Locke.	1·786	....	13·52
Portland	43 41	289 40	Locke.	1·776	....	13·44
				Between the latitudes of 45° and 50°.		
Upper Fort Garry	49 53	262 58	Lefroy.	1·862	....	14·09
Upper Fort Garry	49 53	262 58	Lefroy.	....	2·849	14·05
Lake of the Woods	49 19	265 18	Lefroy.	1·867	....	14·13
Lake of the Woods	49 28	265 20	Lefroy.	1·856	....	14·05
Rat Portage	49 46	265 21	Lefroy.	1·858	....	14·06
Rat Portage	49 46	265 21	Lefroy.	....	2·876	13·97
Rainy River	48 48	265 29	Lefroy.	1·895§	....	14·34
Fort Francis	48 37	266 31	Lefroy.	1·853	....	14·03
Fort Francis	48 37	266 31	Lefroy.	....	3·044	14·18
Lac de la Pluie	48 32	267 04	Lefroy.	1·859	....	14·07
Sturgeon Lake	48 27	267 19	Lefroy.	1·861	....	14·08
2nd Pe. from L. à la Crosse	48 15	267 33	Lefroy.	1·855	....	14·04
Lac à la Crosse	48 24	267 50	Lefroy.	1·860	....	14·08
Portage des deux Rivières	48 35	268 33	Lefroy.	1·862	....	14·09

* Lunatic Asylum, Manhattanville.

† New Lunatic Asylum.

‡ Columbia College.

§ Apparent local disturbance; omitted in the map.

Table XLVIII. (Continued.)

Station.	Lat.	Long.	Observer.	Magnetic force.		
				Relative force. Toronto = 1·836.	In absolute measure.	
					Horizontal.	Total.
	Between the latitudes of 45° and 50° (continued).					
Portage des deux Rivières	48° 35′	268° 33′	Lefroy.	....	2·930	13·89
French Portage	48 35	268 53	Lefroy.	1·860	....	14·08
La Pointe	46 47	269 02	Locke.	1·875	....	14·19
Savannah Portage	48 53	269 57	Lefroy.	1·867	....	14·13
Prairie Portage	48 58	269 59	Lefroy.	1·858	....	14·06
Prairie Portage	48 58	269 59	Lefroy.	....	2·844	14·18
Portage Ecarté	48 25	270 15	Lefroy.	1·852	....	14·02
Portage du Chien	48 39	270 26	Lefroy.	1·865	....	14·12
Portage du Chien	48 39	270 26	Lefroy.	....	2·836	14·17
Ontanogon River	46 52	270 29	Locke.	1·865	....	14·12
Fort William	48 24	270 37	Lefroy.	1·866	....	14·12
Fort William	48 24	270 37	Lefroy.	....	2·875	13·91
Pointe Tonnerre	48 19	270 58	Lefroy.	1·876	....	14·20
Isle Royale	48 06	271 13	Locke.	1·889*	....	14·30
Eagle River	47 27	271 37	Locke.	1·861	....	14·08
United States Agency	47 28	271 59	Locke.	1·950*	....	14·76
Houghton's River	47 28	271 59	Locke.	1·842	....	13·94
Magnetic Inlet	47 29	271 59	Locke.	1·910*	....	14·46
Isthmus	47 28	272 00	Locke.	1·895*	....	14·34
Terreplatte	48 49	272 15	Lefroy.	1·854	....	14·03
Encampment	46 44	272 17	Locke.	1·856	....	14·05
Lake Superior	48 46	272 20	Lefroy.	....	3·213	15·89
Pic Fort	48 38	273 29	Lefroy.	....	2·725	13·84
Pic Fort	48 38	273 29	Lefroy.	1·846	....	13·97
White River	48 33	273 33	Lefroy.	....	2·803	14·12
Otter Island	48 06	273 43	Lefroy.	1·801*	....	13·63
South Manitou Island	45 05	274 22	Younghusband.	1·846	....	13·97
Gargantua	47 37	274 49	Lefroy.	....	3·190	15·26
Michipicoton	47 56	274 55	Lefroy.	1·855	....	14·04
Michipicoton	47 56	274 55	Lefroy.	....	2·870	13·93
Pointe au Crêpe	46 58	275 02	Lefroy.	1·877	....	14·21
Pointe aux Pins	46 29	275 19	Lefroy.	1·862	....	14·09
Machinac	45 52	275 19	Locke.	1·864	....	14·10
Sault St. Mary	46 31	275 26	Lefroy.	....	3·026	13·98
Sault St. Mary	46 31	275 26	Locke.	1·861	....	14·08
Tessalon Point	46 16	276 29	Lefroy.	1·852	....	14·02
Snake Island	46 10	277 10	Lefroy.	1·833	....	13·87
Fort la Cloche	46 07	277 35	Lefroy.	....	3·108	13·64
Lake Huron	46 00	278 10	Lefroy.	1·840	....	13·93
Pointe au Croix	45 55	278 42	Lefroy.	1·852	....	14·02
Ricolet Falls	45 57	278 59	Lefroy.	1·870	....	14·15
Lake Nipissing	46 13	280 01	Lefroy.	1·836	....	13·90
Lake du Grand Vase	46 18	280 34	Lefroy.	1·846	....	13·97
Little River	46 18	281 17	Lefroy.	1·838	....	13·91
Trou Portage	46 15	281 27	Lefroy.	1·841	....	13·93
Deux Joachim's Point	46 12	281 41	Lefroy.	1·830	....	13·85
Pointe Baptême	46 06	282 34	Lefroy.	1·822	....	13·79
Fort Coulange	45 56	282 56	Lefroy.	1·844	....	13·95
Grand Calumet	45 45	283 20	Lefroy.	1·826	....	13·82
Chat Falls	45 26	283 28	Lefroy.	1·840	....	13·93
Point Aylmer	45 29	284 12	Lefroy.	1·825	....	13·81
Cornwall	45 02	284 13	Younghusband.	1·822	....	13·79
Pointe aux Chênes	45 37	285 05	Lefroy.	1·805	....	13·66
La Combes	45 32	285 51	Lefroy.	1·825	....	13·81

* Apparent local disturbance; these are omitted in the map.

TABLE XLVIII. (Continued.)

Station.	Lat.	Long.	Observer.	Magnetic force.		
				Relative scale. Toronto = 1·836.	In absolute measure.	
					Horizontal.	Total.
	Between the latitudes of 45° and 50° (continued).					
	° ′	° ′				
Foxes Point	45 32	286 26	LEFROY.	1·832	....	13·86
Isle d'Urval	45 24	286 14	LEFROY.	1·806	....	13·67
Montreal*	45 30	286 24	YOUNGHUSBAND.	1·788	....	13·53
St. Helen's	45 30	286 24	LEFROY.	1·823	....	13·79
St. Helen's	45 30	286 24	LEFROY.	....	3·064	13·78
Sorel	46 02	287 00	LEFROY.	1·815	....	13·74
Three Rivers	46 19	287 24	LEFROY.	1·826	....	13·82
Kingsey	45 48	287 41	LEFROY.	1·808	....	13·69
Stanstead	45 02	287 50	LEFROY.	1·799	....	13·61
Quebec	46 49	288 44	LEFROY.	....	3·040†	13·78
Quebec	46 49	288 44	LEFROY.	1·827†	....	13·83
Quebec	46 49	288 44	YOUNGHUSBAND.	1·801‡	....	13·63
	Between the latitudes of 50° and 55°.					
Fort Edmonton	53 31	247 08	LEFROY.	1·809	....	13·69
Fort Edmonton	53 31	247 08	LEFROY.	....	2·942	14·04
Saskatchawan River	54 05	248 16	LEFROY.	....	2·829	13·71
Saskatchawan River	53 50	249 30	LEFROY.	....	2·746	13·84
Fort Pitt..............	53 34	250 41	LEFROY.	....	2·778	14·15
Saskatchawan River	53 07	251 30	LEFROY.	....	2·847	14·24
Saskatchawan River	52 23	252 56	LEFROY.	....	2·865	14·09
Carlton House	52 51	253 47	LEFROY.	....	2·737	13·74
Saskatchawan River	53 16	255 12	LEFROY.	....	2·615	13·94
Cumberland House	53 57	257 41	LEFROY.	1·866	....	14·12
Cumberland House	53 57	257 41	LEFROY.	....	2·358	14·12
Beaver Lake	54 32	257 50	LEFROY.	1·869	....	14·14
Near the Pas	53 48	258 32	LEFROY.	....	2·386	14·32
Devil's Drum Island	53 19	259 15	LEFROY.	....	2·399	13·82
Cedar Lake	53 12	259 30	LEFROY.	1·871	....	14·16
Cross Lake............	53 10	260 28	LEFROY.	1·876	....	14·20
Cross Lake............	53 10	260 28	LEFROY.	....	2·352	14·21
Grand Rapid	53 08	260 32	LEFROY.	1·875	....	14·19
Grand Rapid	53 08	260 34	LEFROY.	....	2·343	14·11
Lake Winnipeg	53 31	260 48	LEFROY.	1·862	....	14·09
Norway House	53 59	261 53	LEFROY.	1·873	....	14·18
Norway House	53 59	261 53	LEFROY.	....	2·173	14·18
Old Norway House	53 42	261 59	LEFROY.	1·874	....	14·18
Lake Winnipeg	52 29	262 47	LEFROY.	1·866	....	14·12
Hairy Lake	54 21	262 50	LEFROY.	1·859	....	14·07
Lake Winnipeg	52 23	262 51	LEFROY.	1·879	....	14·22
Lake Winnipeg	52 21	262 51	LEFROY.	....	2·398	14·38
Lake Winnipeg	51 45	263 07	LEFROY.	1·904§	....	14·42
Lake Winnipeg	51 44	263 12	LEFROY.	....	2·763§	15·37
Lake Winnipeg	51 38	263 12	LEFROY.	1·912§	....	14·47
Lake Winnipeg	51 04	263 15	LEFROY.	1·863	....	14·10
Lake Winnipeg	51 34	263 20	LEFROY.	....	2·721	14·40
Lake Winnipeg	50 27	263 22	LEFROY.	1·867	....	14·13

* Garden on the Mountain.

† At the Royal Artillery Barracks, apparent local disturbance; omitted in the map.

‡ Near WOLFE's Monument.

§ Apparent local disturbance; these are omitted in the map.

TABLE XLVIII. (Continued.)

Station.	Lat.	Long.	Observer.	Magnetic force.		
				Relative scale. Toronto = 1·836.	In absolute measure.	
					Horizontal.	Total.
	Between the latitudes of 50° and 55° (continued).					
	° ′	° ′				
White Fall Portage	54 24	263 34	LEFROY.	1·869	....	14·15
Fort Alexander	50 37	263 39	LEFROY.	1·857	....	14·05
Fort Alexander	50 37	263 39	LEFROY.	....	2·698	14·08
Lake Winnipeg	51 04	263 39	LEFROY.	....	2·640	14·52
Mouth of the Red River.	50 19	263 19	LEFROY.	1·864	....	14·11
Windy Lake	54 37	263 58	LEFROY.	1·870	....	14·15
Slave Portage..........	50 11	264 23	LEFROY.	1·867	....	14·13
Oxford House	54 56	264 30	LEFROY.	1·877	....	14·21
Winnipeg River........	50 10	264 51	LEFROY.	1·877	....	14·21
	Between the latitudes of 55° and 60°.					
Fort Dunvegan	55 56	241 35	LEFROY.	1·809	....	13·69
Fort Dunvegan	55 56	241 35	LEFROY.	....	2·732	14·03
Fort Vermilion	58 25	243 55	LEFROY.	1·811	....	13·71
Fort Vermilion	58 25	243 55	LEFROY.	....	2·250	14·07
Lesser Slave Lake......	55 33	244 07	LEFROY.	....	2·731	13·87
Pierre au Calumet......	57 24	248 25	LEFROY.	1·938*	....	14·66
Pierre au Calumet......	57 24	248 25	LEFROY.	...	2·172*	14·33
Pointe Brulée	58 07	248 35	LEFROY.	1·852	....	14·02
Pointe Brulée	58 07	248 35	LEFROY.	...	2·067	14·00
Athabasca	58 43	248 42	LEFROY.	1·838	....	13·91
Athabasca	58 43	248 42	LEFROY.	....	2·030	13·94
Clearwater River	56 39	249 11	LEFROY.	1·850	....	14·00
Clearwater River	56 39	249 11	LEFROY.	....	2·262	13·85
Portage de la Loche	56 34	250 23	LEFROY.	1·835	....	13·89
Portage de la Loche	56 34	250 23	LEFROY.	....	2·278	13·95
River de la Loche......	56 15	250 37	LEFROY.	1·826	....	13·82
River de la Loche......	56 15	250 37	LEFROY.	....	2·336	13·90
Buffaloe Lake	56 05	251 19	LEFROY.	1·854	....	14·03
Buffaloe Lake	56 05	251 19	LEFROY.	....	2·278	13·97
Isle à la Crosse	55 27	252 06	LEFROY.	1·851	....	14·01
Isle à la Crosse	55 27	252 06	LEFROY.	....	2·394	14·01
Portage Sonnante	55 54	252 34	LEFROY.	1·858	....	14·06
Snake Rapid	55 46	253 30	LEFROY.	1·874	....	14·18
Pine Portage	55 43	254 10	LEFROY.	1·884	....	14·26
Great Devil's Portage ..	55 40	255 11	LEFROY.	1·875	....	14·19
Little Rock Portage	55 34	255 27	LEFROY.	1·995*	....	15·10
Frog Portage	55 28	256 30	LEFROY.	1·857	....	14·06
Portage des Epinettes ..	55 04	257 18	LEFROY.	1·871	....	14·16
Long Portage..........	55 15	265 35	LEFROY.	1·879	....	14·22
Hill River	55 22	266 00	LEFROY.	1·871	....	14·16
White Earth Portage....	55 32	266 10	LEFROY.	1·862	....	14·09
Shamatawa............	56 21	267 04	LEFROY.	1·861	....	14·08
York Factory..........	57 00	267 34	LEFROY.	1·854	....	14·03
York Factory..........	57 00	267 34	LEFROY.	....	1·523	14·07
	Between the latitudes of 60° and 67°.					
Fort Good Hope	66 16	231 30	LEFROY.	....	1·678	13·64
Fort Norman	64 31	235 16	LEFROY.	....	1·763	13·63
Fort Resolution	61 10	246 15	LEFROY.	....	1·767	13·99
Fort Simpson..........	61 51	238 35	LEFROY.	....	1·957	13·84

* Local disturbance; omitted in the map.

§ 12. *Observations of the Inclination.*

With Mr. Fox's *apparatus.*—The Inclinations obtained with needle F. A. of Mr. Fox's apparatus were observed with the face of the circle successively to the east and to the west; the mean of the arcs read in the two positions and at both ends of the needle is the result entered in the Table. The observations were made either direct, *i. e.* without the employment of deflectors, or with a deflector placed successively at the same angle on either side of the Inclination, and deflecting the needle to the opposite side: half the sum of the arcs read in the two deflected positions is the result in the Table. The poles of the needle F. A. were at no time reversed. When received in England from the maker in the spring of 1842, the mean of the two arcs with the face east and face west were found to give the true Inclination without sensible index error. At Sorel, in September of the same year, the Inclination obtained with needle F. C. of the same apparatus, of which the poles were on that occasion reversed, was found to agree with that shown by needle F. A. within the usual limits of observation error; and at Toronto in October 1842, the Inclination observed with needle F. A. agreed within the same limits with that observed with GAMBEY's needles of which the poles were reversed. This needle is therefore considered to have had no index error.

With GAMBEY's *Inclinometer.*—This instrument is the property of Captain ROBERT FITZROY of the Royal Navy, by whom it has been kindly lent for general magnetic service. It is the same instrument which was employed by that officer in his voyage of circumnavigation, and was afterwards used by myself in the magnetic survey of the British Islands. It has since travelled with Lieut. LEFROY over the continent of America to the Arctic Circle and back, having been used at more than 100 stations during that journey; and it should be recorded, to the credit of the excellent artist by whom it was made, that it is still in use apparently quite unimpaired.

The observations made with the needles of this instrument in different azimuths, and recorded in the Memoir of the Magnetic Survey of the British Islands*, have shown that the curvature of the axles is without sensible fault, and consequently that there is no index error, whatever may be the Inclination.

The Inclination with GAMBEY's circle and needles entered in the Tables are the mean of the arcs in the sixteen positions of the circle and needle; viz. eight positions with the poles direct, and the same number with the poles reversed.

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* Report of the British Association, 1838, pages 59 and 60.

TABLE XLIX.

Inclinations observed with the Needles of Fox's Apparatus in Canada and the United States in 1842. Needle F. A. was always employed except when otherwise noticed.

Station.	1842.	Direct or with deflectors.	Inclination.	
			° ′	° ′
Quebec[a]	Sept. 1.	Direct.	77 23·0	77 15·3
Quebec[a]	1.	Def. N. at 40°	77 08·5	
Quebec[a]	1.	Def. N. at 50°	77 14·3	
Three Rivers[b]	6.	Direct.	77 13·2	77 10·7
Three Rivers[b]	6.	Def. N. at 40°	77 09·9	
Three Rivers[b]	6.	Def. N. at 50°	77 09·0	
Sorel[c]	8.	Direct.	77 22·6	77 17·7
Sorel[c]	8.	Def. S. at 40°	77 14·3	
Sorel[c]	8.	Def. S. at 50°	77 16·1	
Sorel[d]	8.	Direct.	77 13·9	77 16·8
Sorel[d]	8.	Def. S. at 40°	77 18·0	
Sorel[d]	8.	Def. S. at 50°	77 17·4	
Sorel[e]	8.	Direct.	77 21·6	77 16·3
Sorel[e]	8.	Def. S. at 40°	77 23·3	
Sorel[e]	8.	Def. S. at 50°	77 04·1	
Kingsey[f]	10.	Direct.	77 46·0	77 40·0
Kingsey[f]	10.	Def. N. at 40°	77 39·3	
Kingsey[f]	10.	Def. N. at 50°	77 34·4	
Stanstead[g]	12.	Direct.	76 27·9	76 19·5
Stanstead[g]	12.	Def. N. at 40°	76 14·0	
Stanstead[g]	12.	Def. N. at 50°	76 16·7	
St. John's[h]	14.	Direct.	77 09·1	77 00·1
St. John's[h]	14.	Def. N. at 40°	76 56·0	
St. John's[h]	14.	Def. N. at 50°	76 55·1	
St. Helen's[i] (Montreal).	16.	Direct.	77 20·4	77 13·1
St. Helen's[i] (Montreal).	16.	Def. N. at 40°	77 08·1	
St. Helen's[i] (Montreal).	16.	Def. N. at 50°	77 10·7	
New York[k]	26.	Direct.	72 40·1	72 39·5
New York[k]	26.	Def. N. at 40°	72 35·5	
New York[k]	26.	Def. N. at 50°	72 44·5	
Providence[l]	28.	Direct.	74 02·3	73 59·9
Providence[l]	28.	Def. S. at 40°	73 59·3	
Providence[l]	28.	Def. S. at 50°	73 58·1	
Dorchester[m]	Oct. 1.	Direct.	74 18·6	74 12·8
Dorchester[m]	1.	Def. N. at 40°	74 05·0	
Dorchester[m]	1.	Def. N. at 50°	74 14·9	
Cambridge[n]	Oct. 3.	Direct.	74 23·1	74 19·5
Cambridge[n]	3.	Def. S. at 40°	74 16·7	
Cambridge[n]	3.	Def. S. at 50°	74 18·7	
Philadelphia[o]	6.	Direct.	72 00·9	71 59·0
Philadelphia[o]	6.	Def. N. at 40°	71 58·1	
Philadelphia[o]	6.	Def. N. at 50°	71 58·0	
Baltimore[p]	8.	Direct.	71 34·0	71 36·0
Baltimore[p]	8.	Def. N. at 40°	71 35·4	
Baltimore[p]	8.	Def. N. at 50°	71 38·5	
Baltimore[q]	8.	Direct.	71 47·5	71 47·5
Baltimore[q]	8.	Def. S. at 40°	71 46·7	
Baltimore[q]	8.	Def. S. at 50°	71 49·2	
Baltimore[r]	8.	Direct.	71 41·1	71 40·7
Baltimore[r]	8.	Def. N. at 40°	71 40·4	
Washington[s]	10.	Direct.	71 13·7	71 13·8
Washington[s]	10.	Def. N. at 40°	71 13·8	
Washington[s]	10.	Def. N. at 50°	71 13·9	
Princeton[t]	14.	Direct.	72 46·4	72 43·5
Princeton[t]	14.	Def. N. at 40°	72 40·0	
Princeton[t]	14.	Def. N. at 50°	72 44·0	
Newhaven[u]	18.	Direct.	73 31·4	73 27·4
Newhaven[u]	18.	Def. N. at 40°	73 24·7	
Newhaven[u]	18.	Def. N. at 50°	73 26·2	
West Point[v]	19.	Direct.	73 33·3	73 30·4
West Point[v]	19.	Def. N. at 40°	73 30·1	
West Point[v]	19.	Def. N. at 50°	73 27·6	
Albany[w]	21.	Direct.	74 51·0	74 44·6
Albany[w]	21.	Def. N. at 40°	74 38·7	
Albany[w]	21.	Def. N. at 50°	74 44·2	
Toronto[x]	26.	Direct.	75 19·2	75 16·3
Toronto[x]	26.	Def. S. at 40°	75 14·9	
Toronto[x]	26.	Def. S. at 50°	75 14·8	

Observations made with the same Instrument by Lieut. YOUNGHUSBAND, R.A.

Station.	1842.	Direct or with deflectors.	Inclination.	
			° ′	° ′
Toronto[x]	Oct. 29.	Direct.	75 17·9	75 17·1
Toronto[x]	29.	Def. N. at 40°	75 19·3	
Toronto[x]	29.	Def. N. at 50°	75 14·0	
Cleveland[y]	Nov. 3.	....	73 03·8	73 03·8
Detroit[y]	4.	....	73 28·7	73 28·7
South Manitou Island[z]	7.	Direct.	75 55·8	75 56·6
South Manitou Island[z]	7.	Def. N. at 40°	75 56·5	
South Manitou Island[z]	7.	Def. N. at 50°	75 57·8	
Chicago[a′]	Nov. 15.	Direct.	72 37·6	72 39·3
Chicago[a′]	15.	Def. N. at 40°	72 38·8	
Chicago[a′]	15.	Def. N. at 50°	72 41·6	
Toronto	Dec. 30.	Direct.	75 16·0	75 16·6
Toronto	30.	Def. N. at 40°	75 15·9	
Toronto	30.	Def. N. at 50°	75 17·8	

[a] In front of the Artillery Barracks.
[b] Mr. BELL's garden.
[c] East of the Roman Catholic Church.
[d] Needle C., poles direct α.
[e] Needle C., poles reversed β.
[f] Captain Cox's garden.
[g] Hotel garden.
[h] A quarter of a mile above the bridge.
[i] 100 yards S.S.W. of barracks.
[k] Lunatic Asylum, Manhattanville.
[l] At the Steam-boat landing.
[m] Near Grove Hall.
[n] Garden of Observatory.
[o] Magnetic Observatory.
[p] 400 yards N. 42° E. from Washington's Monument.
[q] 600 yards north of Monument.
[r] St. Mary's College.
[s] In the grounds of the Capitol, west front.
[t] 200 yards east of the College.
[u] Near the Cemetery.
[v] Professor BARTLETT's garden.
[w] N. 39° W. from north tower of the North Dutch Church.
[x] Magnetic Observatory. Inclination observed on the same day with GAMBEY's needles, poles direct and reversed, 75° 17′·6.
[y] By the angles of deflection with weights.
[z] Inland from the wharf.
[a′] Dr. ELDRIDGE's inclosure.

TABLE L.—Observations of the Inclination made with Captain FITZROY's Gambey in 1842, 1843, 1844 and 1845. A large portion of the observations in the countries north of Canada were made by Bombardier HENRY.

Station.	Date.	Needle.	Poles. α Direct. β Reversed.		Inclination.	
				° ′	° ′	
Kingston	1842. Nov. 11.	1	α	77 17·1	77 18·8	77 18·7
Kingston	11.	1	β	77 20·5		
Kingston	14.	2	α	77 14·7	77 19·1	
Kingston	14.	2	β	77 23·6		
Kingston	1843. April 18.	1	α	77 18·0	77 18·1	
Kingston	18.	1	β	77 18·2		
Toronto	1842. Dec. .	1	α	75 14·0	75 14·0	
Toronto	.	1	β			
Hamilton	29.	1	α	74 54·7	74 55·3	74 56·7
Hamilton	29.	1	β	74 56·0		
Hamilton	29.	2	α	74 52·5	74 58·1	
Hamilton	29.	2	β	75 03·6		
Williamsburg	1843. April 20.	1	α	76 30·8	76 31·2	76 30·1
Williamsburg	20.	1	β	76 31·7		
Williamsburg	20.	1	α	76 26·8	76 29·0	
Williamsburg	20.	1	β	76 31·2		
St. Helen's	25.	1	α	76 59·2	77 02·1	77 05·3
St. Helen's	25.	1	β	77 05·1		
St. Helen's	29.	2	α	77 03·6	77 08·6	
St. Helen's	29.	2	β	77 13·7		
Isle d'Urval*	30.	1	α	77 21·1	77 21·1	
Isle d'Urval	30.	1				
La Combes*	May 2.	1	α	76 50·6	76 50·6	
La Combes	2.	1				
Pointe aux Chênes*	3.	1	α	76 55·4	76 55·4	
Pointe aux Chênes	3.	1				
Foxes Point*	4.	1	α	76 35·3	76 35·3	
Foxes Point	4.	1				
Point Aylmer	5.	1	α	76 37·2	76 41·0	
Point Aylmer	5.	1	β	76 44·9		
Chat Falls	6.	1	α	75 11·6	75 16·1	
Chat Falls	6.	1	β	75 20·6		
Grand Calumet	7.	1	α	76 42·4	76 44·4	
Grand Calumet	7.	1	β	76 46·4		
Fort Coulonge	8.	1	α	77 28·8	77 29·7	
Fort Coulonge	8.	1	β	77 30·6		
Pointe Baptême	9.	1	α	77 18·9	77 26·6	
Pointe Baptême	9.	1	β	77 34·3		
2 Joachim's Portage	10.	1	α	77 03·8	77 03·8	
2 Joachim's Portage	10.	1	β	77 03·9		
Trou Portage	11.	1	α	77 24·0	77 24·4	
Trou Portage	11.	1	β	77 24·9		
Little River	12.	1	α	77 26·7	77 28·5	
Little River	12.	1	β	77 30·4		
Lac du Grand Vase	13.	1	α	77 21·5	77 21·7	
Lac du Grand Vase	13.	1	β	77 22·0		
Lake Nipissing	14.	1	α	77 06·2	77 09·5	
Lake Nipissing	14.	1	β	77 12·8		
Ricolet Falls	15.	1	α	76 43·6	76 45·4	
Ricolet Falls	15.	1	β	76 47·3		
Pointe au Croix	16.	1	α	76 30·2	76 31·3	
Pointe au Croix	16.	1	β	76 32·5		
Lake Huron	17.	1	α	77 05·6	77 05·6	
Lake Huron	17.	1	β	77 05·7		
Snake Island	18.	1	α	77 04·7	77 05·5	
Snake Island	18.	1	β	77 06·2		
Tessalon Point	19.	1	α	76 59·2	76 59·3	
Tessalon Point	19.	1	β	76 59·4		
Pointe au Pins	20.	1	α	77 12·0	77 13·4	
Pointe au Pins	20.	1	β	77 14·8		
Pointe au Crêpe	21.	1	α	77 10·3	77 11·5	
Pointe au Crêpe	21.	1	β	77 12·6		
Fort Michipicoton	23.	1	α	78 04·6	78 06·3	
Fort Michipicoton	23.	1	β	78 08·0		
Otter Island	24.	1	α	79 43·6	79 43·6	
Otter Island	24.	1	β	79 43·6		
Pic Fort	25.	1	α	78 45·5	78 45·8	
Pic Fort	25.	1	β	78 46·2		

Station.	Date.	Needle.	Poles. α Direct. β Reversed.		Inclination.	
				° ′	° ′	
Terreplatte	1843. May 27.	1	α	78 52·3	78 53·6	
Terreplatte	27.	1	β	78 54·8		
Pointe Tonnerre	28.	1	α	78 19·8	78 23·2	
Pointe Tonnerre	28.	1	β	78 26·7		
Fort William	29.	1	α	78 09·4	78 09·7	78 10·0
Fort William	29.	1	β	78 10·0		
Fort William	29.	2	α	78 06·8	78 10·4	
Fort William	29.	2	β	78 14·0		
Portage Ecarté	June 2.	1	α	77 13·2	77 13·5	
Portage Ecarté	2.	1	β	77 13·7		
Chien Portage	3.	1	α β	78 26·8	78 26·8	
Prairie Portage	5.	1	α	78 26·2	78 26·2	
Prairie Portage	5.	1	β	78 26·2		
Savannah Portage	7.	1	α	78 19·3	78 21·8	
Savannah Portage	7.	1	β	78 24·3		
French Portage	8.	1	α	78 19·0	78 20·4	
French Portage	8.	1	β	78 21·8		
Portage des deux Rivières	9.	1	α	77 49·3	77 49·4	
Portage des deux Rivières	9.	1	β	77 49·5		
Lac à la Crosse	10.	1	α	77 50·6	77 51·0	
Lac à la Crosse	10.	1	β	77 51·5		
2nd Portage from do.	11.	1	α	77 39·8	77 40·1	
2nd Portage from do.	11.	1	β	77 40·4		
Sturgeon Lake	12.	1	α	77 44·4	77 44·8	
Sturgeon Lake	12.	1	β	77 45·3		
Lac la Pluie	13.	1	α	77 46·5	77 47·9	
Lac la Pluie	13.	1	β	77 49·3		
Fort Francis	14.	1	α	77 26·9	77 27·5	
Fort Francis	14.	1	β	77 28·1		
Rainy River	16.	1	α	77 57·3	77 57·4	
Rainy River	16.	1	β	77 57·5		
Lake of the Woods	17.	1	α	78 02·2	78 03·7	
Lake of the Woods	17.	1	β	78 05·2		
Lake of the Woods	18.	1	α	78 15·8	78 16·7	
Lake of the Woods	18.	1	β	78 17·6		
Rat Portage	20.	1	α	78 07·0	78 07·5	
Rat Portage	20.	1	β	78 08·0		
Upper Fort Garry	July 3.	1	α	78 17·0	78 19·4	78 17·8
Upper Fort Garry	3.	1	β	78 21·3		
Upper Fort Garry	3.	2	α	78 11·4	78 16·3	
Upper Fort Garry	3.	2	β	78 21·2		
Mouth of the Red River	4.	1	α β	78 32·6	78 32·6	
Lake Winnipeg	5.	1	α	79 09·9	79 11·8	
Lake Winnipeg	5.	1	β	79 13·8		
Lake Winnipeg	6.	1	α	79 37·9	79 38·0	
Lake Winnipeg	6.	1	β	79 38·0		
Lake Winnipeg	7.	1	α	79 27·1	79 28·3	
Lake Winnipeg	7.	1	β	79 29·6		
Lake Winnipeg	8.	1	α	80 38·6	80 39·2	
Lake Winnipeg	8.	1	β	80 39·8		
Lake Winnipeg	10.	1	α	80 01·9	80 03·7	80 05·4
Lake Winnipeg	10.	1	β	80 05·6		
Lake Winnipeg	10.	2	α	80 00·8	80 07·2	
Lake Winnipeg	10.	2	β	80 13·7		
Norway House	12.	1	α	81 10·5	81 11·0	81 08·8
Norway House	12.	1	β	81 11·6		
Norway House	13.	1	α	81 05·8	81 06·2	
Norway House	13.	1	β	81 06·6		
Norway House	Aug. 9.	1	α	81 08·9	81 09·4	
Norway House	9.	1	β	81 09·8		
Long Portage (Jack River)	19.	1	α	82 13·2	82 13·9	
Long Portage (Jack River)	19.	1	β	82 14·6		
White Earth Portage	21.	1	α	83 02·1	83 02·9	
White Earth Portage	21.	1	β	83 03·6		

* The poles were not reversed at these four stations.

TABLE L. (Continued.)

Station.	Date.	Needle.	Poles. α Direct. β Reversed.	Inclination.	
	1843.		° ′	° ′	
Shamatawa........	Aug. 22.	1	α 83 35·6	83 36·2	
Shamatawa........	22.	1	β 83 36·7		
York Factory	24.	1	α 83 50·1	83 50·5	83 47·2
York Factory	24.	1	β 83 50·9		
York Factory	24.	2	α 83 40·3	83 44·0	
York Factory	24.	2	β 83 47·6		
Hill River	1.	1	α 82 54·5	82 55·0	
Hill River	1.	1	β 82 55·4		
Oxford House......	3.	1	α 82 37·7	82 38·8	
Oxford House......	3.	1	β 82 39·8		
Windy Lake	4.	1	α 81 56·8	81 57·0	
Windy Lake	4.	1	β 81 57·2		
White Fall Portage	5.	1	α 81 46·6	81 47·9	
White Fall Portage	5.	1	β 81 49·2		
Hairy Lake........	6.	1	α 81 20·4	81 20·9	
Hairy Lake........	6.	1	β 81 21·3		
Old Norway House	12.	1	α 80 43·8	80 45·4	
Old Norway House	12.	1	β 80 47·0		
Lake Winnipeg	14.	1	α 80 16·7	80 16·8	
Lake Winnipeg	14.	1	β 80 16·9		
Grand Rapid	15.	1	α 80 19·5	80 21·5	
Grand Rapid	15.	1	β 80 23·5		
Cross Lake........	16.	1	α 80 27·1	80 28·2	
Cross Lake........	16.	1	β 80 29·4		
Cedar Lake........	18.	1	α 80 06·5	80 07·1	
Cedar Lake........	18.	1	β 80 07·7		
Cumberland House	24.	1	α 80 28·4	80 28·7	80 30·2
Cumberland House	24.	1	β 80 29·1		
Cumberland House	24.	2	α 80 31·1	80 31·8	
Cumberland House	24.	2	β 80 32·4		
Beaver Lake	26.	1	α 80 33·3	80 34·2	
Beaver Lake	26.	1	β 80 35·2		
Carp Portage	27.	1	α 80 39·0	80 39·6	
Carp Portage	27.	1	β 80 40·1		
Portage des Epinettes	28.	1	α 80 52·1	80 52·6	
Portage des Epinettes	28.	1	β 80 53·2		
Frog Portage	29.	1	α 80 57·0	80 59·3	
Frog Portage	29.	1	β 81 01·6		
Little Rock Portage	31.	1	α 80 15·0	80 16·5	
Little Rock Portage	31.	1	β 80 17·9		
Great Devil's Portage	Sept. 1.	1	α 80 29·8	80 30·9	
Great Devil's Portage	1.	1	β 80 31·9		
Pine Portage	3.	1	α 80 40·0	80 40·3	
Pine Portage	3.	1	β 80 40·6		
Snake Rapid	4.	1	α 80 38·4	80 38·7	
Snake Rapid	4.	1	β 80 39·1		
Portage Sonnante ..	7.	1	α 80 09·7	80 11·2	
Portage Sonnante ..	7.	1	β 80 12·7		
Isle à la Crosse	9.	1	α 80 08·1	80 09·1	80 09·8
Isle à la Crosse	9.	1	β 80 10·1		
Isle à la Crosse	9.	2	α 80 08·5	80 10·5	
Isle à la Crosse	9.	2	β 80 12·5		
Buffaloe Lake......	13.	1	α 80 36·7	80 37·0	
Buffaloe Lake......	13.	1	β 80 37·2		
River de la Loche ..	14.	1	α 80 18·7	80 19·7	
River de la Loche ..	14.	1	β 80 20·6		
Portage de la Loche, S. end ..	16.	1	α 80 35·9	80 36·4	
Portage de la Loche, S. end ..	16.	1	β 80 36·8		
Portage de la Loche, N. end ..	17.	1	α 80 36·7	80 38·0	
Portage de la Loche, N. end ..	17.	1	β 80 40·0		
Clearwater River ..	19.	1	α 80 35·8	80 36·2	
Clearwater River ..	19.	1	β 80 36·6		
Pierre au Calumet ..	20.	1	α 81 16·1	81 16·8	
Pierre au Calumet ..	20.	1	β 81 17·5		
Pointe Brulée......	21.	1	α 81 30·2	81 30·6	
Pointe Brulée......	21.	1	β 81 31·1		
Athabasca	30.	1	α 81 36·9	81 37·7	81 37·0
Athabasca	30.	1	β 81 38·4		
Athabasca	30.	2	α 81 37·1	81 37·6	
Athabasca	30.	2	β 81 37·9		

Station.	Date.	Needle.	Poles. α Direct. β Reversed.	Inclination.	
	1844.		° ′	° ′	
Athabasca	Feb. .		α	81 35·4	81 37·0
Athabasca			β		
Near Big Island....	Mar. 18.	1	α 82 02·5	82 08·7	
Near Big Island....	18.	1	β 82 14·9		
Fort Simpson......	28.	1	α 81 52·9	81 54·0	81 52·3
Fort Simpson......	28.	1	β 81 55·2		
Fort Simpson......	May 10.	2	α 81 47·7	81 50·7	
Fort Simpson......	10.	2	β 81 53·8		
Fort Norman	28.	1	α 82 32·2	82 34·3	
Fort Norman	28.	1	β 82 36·5		
Fort Good Hope....	29.	1	α 82 54·7	82 55·8	82 55·9
Fort Good Hope....	29.	1	β 82 57·0		
Fort Good Hope....	29.	2	α 82 52·3	82 56·1	
Fort Good Hope....	29.	2	β 82 59·9		
Fort Resolution	June 22.	1	α 82 41·8	82 43·5	82 44·4
Fort Resolution	22.	1	β 82 45·2		
Fort Resolution	22.	2	α 82 39·4	82 45·4	
Fort Resolution	22.	2	β 82 51·5		
Portage Gr. Detour	25.	1	α 82 31·6	82 33·6	
Portage Gr. Detour	25.	1	β 82 35·6		
Pelican Portage	27.	1	α 82 24·4	82 26·8	
Pelican Portage	27.	1	β 82 29·2		
Point Providence ..	July 5.	1	α 81 42·9	81 46·1	
Point Providence ..	5.	1	β 81 49·3		
Peace River	7.	1	α 81 34·2	81 36·9	
Peace River	7.	1	β 81 39·6		
Poplar Island	9.	1	α 81 04·5	81 04·8	
Poplar Island	9.	1	β 81 05·2		
Falls of Peace River	10.	1	α 80 50·5	80 50·8	
Falls of Peace River	10.	1	β 80 51·2		
Fort Vermilion	11.	1	α 80 46·9	80 48·4	80 48·0
Fort Vermilion	11.	1	β 80 50·0		
Fort Vermilion	11.	2	α 80 44·7	80 47·6	
Fort Vermilion	11.	2	β 80 50·6		
Peace River	17.	1	α 79 26·4	79 27·0	
Peace River	17.	1	β 79 27·7		
Peace River	15.	1	α 79 59·2	80 00·7	
Peace River	15.	1	β 80 02·3		
Peace River, opp. River Cadotte ..	19.	1	α 79 20·1	79 20·7	
Peace River, opp. River Cadotte ..	19.	1	β 79 21·4		
Fort Dunvegan	22.	1	α 78 43·8	78 45·7	78 46·2
Fort Dunvegan	22.	1	β 78 47·6		
Fort Dunvegan	22.	2	α 78 45·8	78 46·8	
Fort Dunvegan	22.	2	β 78 47·8		
Lesser Slave Lake F.	Aug. 3.	1	α 78 34·5	78 36·2	78 39·0
Lesser Slave Lake F.	3.	1	β 78 37·9		
Lesser Slave Lake F.	3.	2	α 78 39·3	78 41·9	
Lesser Slave Lake F.	3.	2	β 78 44·5		
Point Dejala, Lesser Slave L.	6.	1	α 78 28·7	78 29·9	
Point Dejala, Lesser Slave L.	6.	1	β 78 31·1		
Forks of Athabasca and Slave River	7.	1	α 78 53·3	78 55·2	
Forks of Athabasca and Slave River	7.	1	β 78 57·1		
Athabasca River....	9.	1	α 78 33·7	78 34·1	
Athabasca River....	9.	1	β 78 34·6		
Fort Assiniboine......	12.	1	α 78 15·6	78 16·9	78 15·2
Fort Assiniboine....	12.	1	β 78 18·3		
Fort Assiniboine....	12.	2	α 78 13·2	78 13·5	
Fort Assiniboine....	12.	2	β 78 13·8		
Pembina River	14.	1	α 77 53·8	77 54·0	
Pembina River	14.	1	β 77 54·3		
Fort Edmonton	17.	1	α 77 52·2	77 53·4	77 54·2
Fort Edmonton	17.	1	β 77 54·7		
Fort Edmonton	17.	2	α 77 54·4	77 55·1	
Fort Edmonton	17.	2	β 77 55·8		
Saskatchawan River	20.	1	α 78 04·8	78 05·2	
Saskatchawan River	20.	1	β 78 05·7		
Saskatchawan River	21.	1	α 78 33·3	78 33·5	
Saskatchawan River	21.	1	β 78 33·7		

TABLE L. (Continued.)

Station.	Date.	Needle.	Poles. α Direct. β Reversed.	Inclination.	
	1844.		° ′	° ′	
Fort Pitt..........	Aug. 22.	1	α 78 42·2	78 43·0	78 41·0
Fort Pitt..........	22.	1	β 78 43·8		
Fort Pitt..........	22.	2	α 78 38·9	78 39·1	
Fort Pitt..........	22.	2	β 78 40·4		
Saskatchawan River	23.	1	α 78 28·1	78 28·1	
Saskatchawan River	23.	1	β 78 28·1		
Saskatchawan River	24.	1	α 78 16·1	78 16·6	
Saskatchawan River	24.	1	β 78 17·1		
Carlton House	26.	1	α 78 30·1	78 30·2	78 30·7
Carlton House	26.	1	β 78 30·3		
Carlton House	26.	2	α 78 30·5	78 31·2	
Carlton House	26.	2	β 78 31·9		
Saskatchawan River[a]	27.	1	α 79 11·2	79 11·2	
Saskatchawan River[a]	27.	1	β 79 11·2		
Cumberland House .	29.	1	α 80 19·6	80 20·5	80 19·7
Cumberland House .	29.	1	β 80 21·5		
Cumberland House .	29.	2	α 80 18·1	80 19·0	
Cumberland House .	29.	2	β 80 19·9		
Above the Pas	31.	1	α 80 24·4	80 24·4	
Above the Pas	31.	1	β 80 24·4		
Devil's Drum Island	Sept. 1.	1	α 79 59·2	80 00·0	
Devil's Drum Island	1.	1	β 80 00·8		
Grand Rapid	2.	1	α 80 30·6	80 31·6	
Grand Rapid	2.	1	β 80 32·7		
Norway House	7.	1	α 81 10·5	81 11·1	81 11·2
Norway House	7.	1	β 81 11·7		
Norway House	7.	2	α 81 10·8	81 11·4	
Norway House	7.	2	β 81 12·0		
Lake Winnipeg	14.	1	α 80 24·4	80 24·4	
Lake Winnipeg	14.	1	β 80 24·4		
Lake Winnipeg	16.	1	α 79 38·9	79 39·0	
Lake Winnipeg	16.	1	β 79 39·1		
Lake Winnipeg	17.	1	α 79 05·9	79 06·1	
Lake Winnipeg	17.	1	β 79 06·4		
Lake Winnipeg	18.	1	α 79 31·2	79 31·5	
Lake Winnipeg	18.	1	β 79 31·8		
Fort Alexander	19.	1	α 79 03·2	79 03·4	79 02·9
Fort Alexander	19.	1	β 79 03·7		
Fort Alexander	19.	2	α 79 02·5	79 02·5	
Fort Alexander	19.	2	β 79 02·5		
Fort Francis	30.	1	α 77 38·2	77 41·4	77 42·9
Fort Francis	30.	1	β 77 44·7		
Fort Francis	30.	2	α 77 44·0	77 44·5	
Fort Francis	30.	2	β 77 45·1		
Fort William	Oct. .	1	α 78 07·2	78 07·5	77 59·5
Fort William	.	1	β 78 07·9		
Fort William	.	2	α 77 55·2	77 55·5	
Fort William	.	2	β 77 55·8		
Fort William	.	1*	α 77 54·9	77 55·5	
Fort William	.	1	β 77 56·1		
S.shore Lake Superior	14.	1	α 78 23·2	78 24·0	
S.shore Lake Superior	14.	1	β 78 24·8		
Pic Fort	17.	1	α 78 32·0	78 32·8	78 31·4
Pic Fort	17.	1	β 78 33·6		
Pic Fort	17.	2	α 78 29·9	78 30·1	
Pic Fort	17.	2	β 78 30·4		
White River	21.	1	α 78 33·4	78 33·7	78 33·1
White River	21.	1	β 78 34·1		
White River	21.	2	α 78 31·2	78 32·5	
White River	21.	2	β 78 33·8		
	1844.		° ′	° ′	
Fort Michipicoton ..	Oct. 30.	1	α 78 07·8	78 08·1	78 08·2
Fort Michipicoton ..	30.	1	β 78 08·4		
Fort Michipicoton ..	30.	2	α 78 08·4	78 08·3	
Fort Michipicoton ..	30.	2	β 78 08·5		
Gargantua	31.	1	α 77 56·1	77 56·1	
Gargantua	31.	1	β 77 56·1		
Fort la Cloche	8.	1	α 76 50·7	76 50·7	76 50·2
Fort la Cloche	8.	1	β 76 50·8		
Fort la Cloche	8.	2	α 76 49·2	76 49·7	
Fort la Cloche	8.	2	β 76 50·3		
Penetanguishene ..	14.	1	α 76 18·9	76 19·2	76 20·1
Penetanguishene ..	14.	1	β 76 19·5		
Penetanguishene ..	14.	2	α 76 21·0	76 21·0	
Penetanguishene ..	14.	2	β 76 21·1		
	1845.				
Kingston*[b]	June 10.	1	α 77 11·1	77 14·2	77 14·4
Kingston*[b]	10.	1	β 77 17·3		
Kingston*[b]	10.	2	α 77 09·9	77 14·7	
Kingston*[b]	10.	2	β 77 19·5		
Brockville*[c]	13.	1	α 76 17·7	76 19·8	76 18·9
Brockville*[c]	13.	1	β 76 21·9		
Brockville*[c]	13.	2	α 76 12·7	76 18·0	
Brockville*[c]	13.	2	β 76 23·4		
Cornwall*[d]........	16.	1	α 76 14·7	76 16·5	76 16·4
Cornwall*[d]........	16.	1	β 76 18·3		
Cornwall*[d]........	16.	2	α 76 10·2	76 16·3	
Cornwall*[d]........	16.	2	β 76 22·4		
Montreal*[e]........	18.	1	α 77 03·0	77 06·7	77 08·6
Montreal*[e]........	18.	1	β 77 10·5		
Montreal*[e]........	20.	2	α 77 05·9	77 10·3	
Montreal*[e]........	20.	2	β 77 14·7		
Montreal*[e]........	20.	1	α 77 03·7	77 08·9	
Montreal*[e]........	20.	1	β 77 14·1		
Quebec*[f]	23.	1	α 77 04·7	77 08·8	
Quebec*[f]	23.	1	β 77 12·9		
Niagara[g]..........	Oct. 18.	1	α 74 46·3	74 46·8	
Niagara[g]..........	18.	1	β 74 47·3		
Buffaloe[h]	20.	1	α 74 35·6	74 37·8	74 37·0
Buffaloe[h]	20.	1	β 74 42·2		
Buffaloe[h]	20.	2	α 74 31·8	74 36·2	
Buffaloe[h]	20.	2	β 74 40·6		
Amherstburg[i]......	22.	1	α 73 26·1	73 32·7	73 29·9
Amherstburg[i]......	22.	1	β 73 39·2		
Amherstburg[i]......	22.	2	α 73 21·5	73 27·2	
Amherstburg[i]......	22.	2	β 73 32·9		
Detroit[k]..........	23.	1	α 73 34·5	73 40·6	73 38·8
Detroit[k]..........	23.	1	β 73 46·8		
Detroit[k]..........	23.	2	α 73 31·5	73 37·0	
Detroit[k]..........	23.	2	β 73 42·5		
Port Sarnia[l]	25.	1	α 74 14·7	74 18·6	74 15·7
Port Sarnia[l]	25.	1	β 74 22·6		
Port Sarnia[l]	26.	2	α 74 07·8	74 12·9	
Port Sarnia[l]	26.	2	β 74 18·0		
Goderich[m]	28.	1	α 75 03·9	75 04·4	75 04·8
Goderich[m]	28.	1	β 75 05·0		
Goderich[m]	28.	2	α 75 03·4	75 05·3	
Goderich[m]	28.	2	β 75 07·3		
Hamilton	31.	1	α 74 51·9	74 54·1	
Hamilton	31.	1	β 74 56·3		

[a] Below the forks of the north and south branches.

* The observation with Needle No. 1 was repeated in consequence of the difference between the results with Nos. 1 and 2.

* Observed by Lieut. YOUNGHUSBAND, R.A.

[b] Royal Artillery Barracks.

[c] Garden at Rockfort.

[d] Orchard behind Chesleys.

[e] Garden on the Mountain.

[f] Near WOLFE's Monument.

[g] Near the Clifton Hotel.

[h] Behind the High School.

[i] Garden of the Hon. J. GORDON.

[k] North-west corner of Lafayette and Orleans Straits.

[l] Garden near the Ferry.

[m] Garden at the foot of the hill.

TABLE LI. General Table of the Observations of the Magnetic Inclination.

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
	Between 68° 30′ and 69° 30′.					
	° ′	° ′			° ′	° ′
Princeton	38 23	272 30	1840.	LOCKE.	69 22·8	
Mount Vernon	37 59	272 13	1840.	LOCKE.	68 56·3	
New Harmony	38 11	272 12	1840.	LOCKE.	69 03·6	
St. Louis	38 38	269 56	1839.	LOCKE.	69 31·4	69 27·9
St. Louis	38 38	269 56	1841.	LOOMIS.	69 25·5	
St. Louis	38 38	269 56	1841.	NICOLLET.	69 26·9	
	69° 30′ to 70° 30′.					
Lexington	38 06	275 42	1840.	LOCKE.	69 54·5	
Clay's Ferry	37 54	275 42	1840.	LOCKE.	69 49·0	
Cincinnati	39 06	275 38	1838 to 1844.	LOCKE.	70 26·5	70 27·1
Cincinnati	39 06	275 38	1841.	LOOMIS.	70 27·7	
Williamstown	38 36	275 38	1840.	LOCKE.	70 04·1	
Frankfort	38 14	275 20	1840.	LOCKE.	69 54·9	
Louisville	38 03	274 30	1840.	LOCKE.	69 54·4	
Paoli	38 05	273 35	1840.	LOCKE.	69 33·8	
Vincennes	38 43	272 35	1840.	LOCKE.	69 51·0	69 51·9
Vincennes	38 43	272 31	1841.	LOOMIS.	69 52·8	
Edwardsville	38 50	270 07	1841.	LOOMIS.	69 57·7	
Bunker's Hill	39 04	270 07	1841.	LOOMIS.	69 49·1	
Upper Alton	38 55	269 57	1841.	LOOMIS.	69 45·7	
Alton	38 54	269 56	1841.	LOOMIS.	69 34·8	
Monticello	38 57	269 55	1841.	LOOMIS.	69 38·9	
	70° 30′ to 71° 30′.					
Washington[a]	38 53	282 59	1839.	LOOMIS.	71 21·4	71 15·0
Washington[a]	38 53	282 59	1841.	GRAHAM.	71 15·9	
Washington[a]	38 53	282 59	1844.	GRAHAM.	71 10·5	
Washington[a]	38 53	282 59	1841.	NICOLLET.	71 14·8	
Washington[a]	38 53	282 59	1842.	LEFROY.	71 13·8	
Washington[a]	38 53	282 59	1844.	LOCKE.	71 13·4	
Washington[b]	38 53	282 59	1844.	LOCKE.	71 39·3	
Washington[c]	38 53	282 59	1844.	LOCKE.	71 34·8	
Washington[d]	38 53	282 59	1844.	LOCKE.	71 14·9	
Washington[e]	38 53	282 59	1844.	LOCKE.	71 20·5	
Georgetown	38 53	282 57	1844.	LOCKE.	71 19·0	
Mount Vernon	38 41	282 53	1844.	LOCKE.	70 55·5	
Marietta Island	39 25	278 32	1845.	LOCKE.	71 22·3	
Hebron	39 59	277 31	1841.	LOOMIS.	71 10·1	
Columbus	39 57	276 57	1840.	LOCKE.	71 04·9	71 04·3
Columbus	39 57	276 57	1841.	LOOMIS.	71 03·7	
Columbus	39 57	276 57	1845.	LOCKE.	71 04·3	
Springfield	39 54	276 09	1840.	LOCKE.	71 27·4	
Lebanon	39 26	275 54	1840.	LOCKE.	71 02·7	
Carrolton	39 38	275 51	1845.	LOCKE.	71 10·0	
Mason	39 22	275 47	1840.	LOCKE.	70 54·2	
Dayton	39 44	275 43	1838.	LOCKE.	71 22·7	71 22·3
Dayton	39 44	275 43	1840.	LOCKE.	71 22·0	
Hamilton	39 23	275 28	1840.	LOCKE.	70 58·0	
Oxford	39 30	275 22	1845.	LOCKE.	71 10·0	
Richmond	39 49	275 13	1845.	LOCKE.	71 20·3	
Pekin	40 35	270 24	1841.	LOOMIS.	71 13·2	

[a] Grounds East or West or in front of the Capitol.
[b] Magnetic Observatory.
[c] Old Depôt near Georgetown.
[d] Near the Patent Office.
[e] Near the War Office.

TABLE LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
	71° 30′ to 72° 30′.					
New York (New Asylum). .	40° 48′	285° 58′	1841.	LOCKE.	72° 21′·0	° ′
Trenton	40 13	285 20	1841.	LOCKE.	71 59·0	
Bristol	40 06	285 13	1842.	LOCKE.	72 25·0	
Philadelphia[a]	39 58	284 50	1844.	GRAHAM.	72 09·2	
Philadelphia[b]	39 58	284 50	1839.	LOOMIS.	72 07·1	
Philadelphia[c]	39 58	284 50	1841.	GRAHAM. BACHE.	71 54·5	71 58·7
Philadelphia	39 58	284 50	1841.	BACHE.	71 58·2	
Philadelphia	39 58	284 50	1841.	LOCKE.	72 00·2	
Philadelphia	39 58	284 50	1842.	LEFROY.	71 59·0	
Philadelphia	39 58	284 50	1842.	LOCKE.	72 01·0	
Philadelphia	39 58	284 50	1844.	LOCKE.	71 59·3	
Cumberland	40 13	283 10	1844.	LOCKE.	71 36·0	
Baltimore[d]	39 17	283 23	1839.	LOOMIS.	71 50·3	71 48·8
Baltimore[d]	39 17	283 23	1841.	GRAHAM.	71 47·2	
Baltimore[d]	39 17	283 23	1841.	NICOLLET.	71 50·1	
Baltimore[d]	39 17	283 23	1842.	LEFROY.	71 47·5	
Baltimore[e]	39 17	283 23	1840.	BACHE.	71 34·4	71 34·1
Baltimore[e]	39 17	283 23	1841.	NICOLLET.	71 35·4	
Baltimore[e]	39 17	283 23	1841.	GRAHAM.	71 32·0	
Baltimore[e]	39 17	283 23	1842.	LEFROY.	71 36·0	
Baltimore[e]	39 17	283 23	1844.	GRAHAM.	71 32·5	
Baltimore[e]	39 17	283 23	1841.	LOCKE.	71 34·1	
Baltimore[f]	39 17	283 23	1841.	GRAHAM.	71 48·2	71 49·5
Baltimore[f]	39 17	283 23	1841.	GRAHAM.	71 50·7	
Baltimore[g]	39 17	283 22	1841.	NICOLLET.	71 39·7	71 39·6
Baltimore[g]	39 17	283 22	1841.	LOCKE.	71 39·2	
Baltimore[g]	39 17	283 22	1841.	GRAHAM.	71 38·9	
Baltimore[g]	39 17	283 22	1842.	LEFROY.	71 40·7	
Baltimore[g]	39 17	283 22	1844.	GRAHAM.	71 39·5	
Mount St. Mary's	39 41	282 42	1842.	LOCKE.	71 46·3	
Chambersburg	39 55	282 20	1842.	LOCKE.	71 57·4	
Allegheny Summit	40 27	281 50	1845.	LOCKE.	72 27·1	
Wheeling	40 08	279 13	1844.	LOCKE.	72 19·3	72 16·5
Wheeling	40 08	279 13	1845.	LOCKE.	72 13·7	
Dover	40 33	278 30	1841.	LOOMIS.	72 19·2	
Frazerburg	40 09	277 52	1841.	LOOMIS.	71 48·7	
Urbana	40 05	276 12	1840.	LOCKE.	71 39·7	
Piqua	40 06	275 47	1840.	LOCKE.	71 35·8	
St. Mary's	40 32	275 41	1845.	LOCKE.	72 00·3	
Ottawa	41 15	271 10	1841.	NICOLLET.	72 20·2	
Juliet	41 30	271 09	1841.	NICOLLET.	72 16·0	
Peru	41 23	270 55	1841.	LOOMIS.	71 51·1	71 50·3
Peru	41 23	270 55	1841.	NICOLLET.	71 49·6	
Lostgrove	41 39	269 51	1839.	LOCKE.	72 02·4	
Wabisepinnecon River	41 44	269 37	1839.	LOCKE.	72 15·0	
Davenport	41 30	269 34	1839.	LOCKE.	71 55·1	
Brown's Settlement	42 02	268 54	1839.	LOCKE.	72 21·0	
	72° 30′ to 73° 30′.					
Stonington	41 20	288 05	1845.	RENWICK.	73 25·1	
Greenport	41 06	287 38	1845.	RENWICK.	72 57·9	
Newhaven	41 18	287 02	1839.	LOOMIS.	73 26·7	73 26·2
Newhaven	41 18	287 02	1842.	LEFROY.	73 27·4	
Newhaven	41 18	287 02	1842.	LOCKE.	73 29·8	
Newhaven	41 18	287 02	1844.	RENWICK.	73 20·9	

[a] Rittenhouse Square. [b] In front of Dr. BACHE's House. [c] Girard College.

[d] [e] [f] are three stations in the grove which extends N. and E. of the Washington Monument.

[g] St. Mary's College

TABLE LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
	72° 30′ to 73° 30′ (continued).					
	° ′	° ′			° ′	° ′
Bridgeport	41 11	286 48	1845.	RENWICK.	73 21·3	
West Point	41 24	285 59	1839.	LOOMIS.	73 27·4	73 28·8
West Point	41 24	285 59	1840.	GRAHAM.	73 20·1	
West Point	41 24	285 59	1841.	BACHE.	73 37·2	
West Point	41 24	285 59	1842.	LEFROY.	73 30·4	
New York, Columbia College	40 43	285 59	1834.	BACHE.	72 51·7	72 44·5
New York, Columbia College	40 43	285 59	1844.	RENWICK.	72 38·0	
New York, Columbia College	40 43	285 59	1839.	LOOMIS.	72 52·2	
New York, Columbia College	40 43	285 59	1841.	LOCKE.	72 41·0	
New York, Columbia College	40 43	285 59	1844.	LOCKE.	72 42·6	
New York, Columbia College	40 43	285 59	1845.	RENWICK.	72 40·6	
Sandy Hook	40 27	285 58	1844.	RENWICK.	72 37·9	
Lunatic Asylum, Manhattanville	40 49	285 57	1841.	LOCKE.	72 39·6	72 42·5
Lunatic Asylum, Manhattanville	40 49	285 57	1844.	LOCKE.	72 41·7	
Lunatic Asylum, Manhattanville	40 49	285 57	1842.	LEFROY.	72 39·5	
Lunatic Asylum, Manhattanville	40 49	285 57	1844.	RENWICK.	72 49·0	
Newark	40 43	285 50	1841.	LOCKE.	72 49·0	72 48·6
Newark	40 43	285 50	1844.	LOCKE.	72 48·3	
New Brunswick	40 30	285 25	1844.	LOCKE.	72 43·2	
Princeton[a]	40 30	285 25	1844.	LOCKE.	72 41·4	
Princeton[b]	40 30	285 25	1844.	LOCKE.	72 35·9	
Princeton	40 22	285 20	1839.	LOOMIS.	72 47·1	72 42·6
Princeton	40 22	285 20	1842.	LEFROY.	72 43·5	
Princeton	40 22	285 20	1844.	LOOMIS.	72 39·5	
Princeton	40 22	285 20	1844.	LOCKE.	72 40·4	
Pittsburg	40 32	279 58	1839.	LOOMIS.	72 38·9	72 43·1
Pittsburg	40 32	279 58	1841.	LOCKE.	72 43·5	
Pittsburg	40 32	279 58	1842.	LOCKE.	72 43·2	
Pittsburg	40 32	279 58	1845.	LOCKE.	72 46·7	
Beaver	40 44	279 33	1839.	LOOMIS.	72 40·3	
Hartford	41 19	279 26	1840.	LOOMIS.	72 59·8	
Kinsman	41 30	279 26	1840.	LOOMIS.	73 08·1	
Wellsville	40 38	279 16	1844.	LOCKE.	72 35·3	
Bazetta	41 20	279 15	1840.	LOOMIS.	72 59·7	
Warren	41 16	279 11	1840.	LOOMIS.	73 00·7	72 58·3
Warren	41 16	279 11	1844.	LOCKE.	72 55·9	
Ashtabula	41 52	279 08	1844.	LOCKE.	73 25·0	
Windham	41 15	278 57	1840.	LOOMIS.	73 03·4	
Shakersville	41 15	278 47	1840.	LOOMIS.	72 56·6	
Streetsboro	41 15	278 40	1840.	LOOMIS.	72 53·0	
Aurora	41 20	278 40	1840.	LOOMIS.	72 55·5	
Twinsburgh	41 20	278 34	1840.	LOOMIS.	72 51·3	
Hudson	41 15	278 34	1838 to 1842.	LOOMIS.	72 48·4	
Tallmadge	41 06	278 33	1840. 1841.	LOOMIS.	72 50·7	
Bedford	41 24	278 28	1840.	LOOMIS,	72 58·1	
Fulton	40 55	278 22	1841.	LOOMIS.	72 38·9	
Clinton	40 58	278 20	1841.	LOOMIS.	72 44·0	
Cleveland	41 30	278 18	1839.	LOOMIS.	73 26·0	73 11·2
Cleveland	41 30	278 18	1840.	LOOMIS.	73 14·1	
Cleveland	41 30	278 18	1841.	LOOMIS.	73 04·3	
Cleveland	41 30	278 18	1842.	YOUNGHUSBAND.	73 03·8	
Cleveland	41 30	278 18	1843.	LOCKE.	73 08·0	
Brooklyn	41 30	278 17	1841.	LOOMIS.	73 16·3	
Huron	41 26	277 33	1843.	LOCKE.	73 00·0	
Sandusky	41 29	277 13	1839.	LOOMIS.	72 57·8	
Amherstburg	42 06	276 47	1845.	LEFROY.	73 29·9	

[a] Pott's Wood. [b] Rock Hills (trap).

Table LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
	72° 30′ to 73° 30′ (continued).					
Munroe	41° 55′	276° 32′	1839.	Loomis.	73° 32′·3	73° 25′·6
Munroe	41 55	276 32	1841.	Loomis.	73 19·0	
Toledo	41 41	276 28	1839.	Loomis.	73 06·1	
Maumee	41 34	276 23	1839.	Loomis.	72 49·1	
Ypsilanti	42 14	276 22	1839.	Loomis.	73 18·0	73 18·4
Ypsilanti	42 14	276 22	1841.	Loomis.	73 18·8	
Ann Arbor	42 18	276 15	1839.	Loomis.	73 13·9	73 14·7
Ann Arbor	42 18	276 15	1841.	Loomis.	73 16·5	
Ann Arbor	42 18	276 15	1843.	Locke.	73 13·6	
Chicago	41 53	272 16	1841.	Loomis.	72 47·8	72 44·3
Chicago	41 53	272 16	1841.	Nicollet.	72 45·8	
Chicago	41 53	272 16	1842.	Younghusband.	72 39·3	
Campbells	43 01	270 34	1841.	Loomis.	73 28·1	
Mineral Point	42 50	270 02	1839.	Locke.	73 20·6	73 21·8
Mineral Point	42 50	270 02	1841.	Loomis.	73 23·0	
Galena	42 28	269 47	1841.	Loomis.	73 03·0	
Platteville	42 43	269 46	1841.	Loomis.	73 17·2	
Farmer's Creek	42 13	269 37	1839.	Locke.	72 36·0	
Dubuques Town	42 29	269 37	1839.	Locke.	73 05·0	
Little Mahoqueta	42 31	269 29	1839.	Locke.	73 08·0	
White Water River	42 18	269 22	1839.	Locke.	72 55·0	
Iron Ore Bed	41 55	269 20	1839.	Locke.	72 50·5	
Turkey River	42 42	269 12	1839.	Locke.	73 11·0	
Mahoqueta, North Branch	42 23	269 08	1839.	Locke.	72 51·0	
Mahoqueta River	42 14	269 05	1839.	Locke.	72 43·6	
Prairie du Chien	43 01	268 51	1839.	Locke.	73 16·6	
	73° 30′ to 74° 30′.					
Boston	42 22	289 01	1842.	Locke.	74 05·7	
Boston	42 21	288 56	1841.	Graham.	74 09·4	
Dorchester	42 19	288 55	1842.	Lefroy.	74 12·8	
Cambridge	42 22	288 52	1839.	Loomis.	74 20·1	74 18·2
Cambridge	42 22	288 52	1841.	Graham and Bond.*	74 17·3	
Cambridge	42 22	288 52	1842.	Locke.	74 14·8	
Cambridge	42 22	288 52	1842.	Lefroy.	74 19·5	
Cambridge	42 22	288 52	1845.	Locke.	74 19·4	
Cambridge, New Observatory	42 23	288 52	1844.	Graham.	74 18·2	
Providence	41 50	288 35	1839.	Loomis.	73 59·6	74 01·1
Providence	41 50	288 35	1841.	Bache.	74 02·8	
Providence	41 49	288 35	1842.	Lefroy.	74 00·0	
Worcester	42 16	288 12	1839.	Loomis.	74 20·6	
Springfield	42 06	287 24	1839.	Loomis.	74 06·9	74 08·8
Springfield	42 06	287 24	1841.	Bache.	74 10·7	
Longmeadow	42 02	287 24	1839.	Loomis.	74 05·3	
Harford	41 46	287 19	1839.	Loomis.	73 58·1	
Powkeepsie	41 41	286 05	1844.	Locke.	73 57·7	
Opposite Powkeepsie	41 41	286 04	1844.	Locke.	74 12·3	
Port Sarnia	42 58	277 26	1845.	Lefroy.	74 15·7	
Detroit	42 24	277 00	1845.	Lefroy.	73 38·8	73 35·0
Detroit	42 25	277 00	1839.	Loomis.	73 42·6	
Detroit	42 25	277 00	1841.	Loomis.	73 35·2	
Detroit	42 25	277 00	1841.	Nicollet.	73 32·7	
Detroit	42 25	277 00	1842.	Younghusband.	73 28·7	
Detroit	42 25	277 00	1843.	Locke.	73 32·2	

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* Mr. William Cranch Bond, Director of the Cambridge Observatory. This result is the mean of 288 observations with two needles.

Table LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
			73° 30′ to 74° 30′ (continued).			
Madison	43° 04′	270° 54′	1839.	Locke.	74° 03′·0	74° 04′·7
Madison	43 03	270 54	1841.	Loomis.	74 06·5	
Blue Mound	43 01	270 22	1839.	Locke.	73 41·0	73 38·0
Blue Mound	43 00	270 22	1841.	Loomis.	73 34·9	
Hickoks	42 58	270 13	1841.	Loomis.	73 39·5	
			74° 30′ to 75° 30′.			
Portland	43 41	289 40	1845.	Locke.	75 13·7	
Portsmouth	43 05	289 16	1844.	Graham and Whipple.*	74 47·7	74 51·0
Portsmouth	43 03	289 16	1844.		74 38·0	
Portsmouth	43 04	289 13	1844.		74 53·7	
Portsmouth	43 04	289 15	1844.		74 58·2	
Portsmouth	43 05	289 15	1844.		74 57·4	
Greenbush	42 39	286 16	1844.	Locke.	74 40·6	
Albany	42 39	286 15	1839.	Loomis.	74 51·3	74 43·2
Albany	42 39	286 15	1841.	Bache.	74 40·1	
Albany	42 39	286 15	1841.	Nicollet.	74 39·9	
Albany	42 39	286 15	1842.	Lefroy.	74 44·6	
Albany	42 39	286 15	1844.	Locke.	74 40·2	
Schenectady	42 48	286 05	1839.	Loomis.	74 36·1	
Utica	43 07	284 47	1839.	Loomis.	74 57·2	74 53·0
Utica	43 07	284 47	1844.	Locke.	74 48·8	
Syracuse	43 00	283 46	1839.	Loomis.	74 50·9	
Chat Falls	45 26	283 28	1843.	Lefroy.	75 16·1†	
Oswego	43 26	283 24	1839.	Loomis.	75 11·3	75 09·7
Oswego	43 26	283 24	1841.	Nicollet.	75 08·1	
Rochester	43 08	282 09	1844.	Locke.	74 38·8	
Lockport	43 11	281 14	1844.	Locke.	74 44·2	
Buffaloe	42 53	281 06	1839.	Loomis.	74 40·8	74 38·1
Buffaloe	42 53	281 06	1844.	Locke.	74 36·5	
Buffaloe	42 52	281 06	1845.	Lefroy.	74 37·0	
Niagara	43 05	280 51	1841.	Nicollet.	74 52·4	74 49·6
Niagara	43 05	280 51	1845.	Lefroy.	74 46·8	
Toronto Observatory	43 39	280 39	1841. 1845.	Lefroy and Younghusband.	75 15·5	75 15·0
Toronto Observatory	43 39	280 39	1844.	Locke.	75 13·4	
Near Toronto	43 39	280 41	1844.	Locke.	75 12·5	
Hamilton	43 16	280 04	1842.	Lefroy.	74 56·7	74 55·4
Hamilton	43 16	280 04	1845.	Lefroy.	74 54·1	
Goderich	43 45	278 08	1845.	Lefroy.	75 04·8	
			75° 30′ to 76° 30′.			
Bangor	44 48	291 13	1841.	Graham.	76 11·6	
Forks of the Kennebec	45 20	290 02	1844.	Graham.	76 23·7	
Locke's Mills	44 24	289 16	1845.	Locke.	75 50·7	
Bethel	44 27	289 09	1845.	Locke.	75 51·0	
Goreham	44 27	288 47	1845.	Locke.	75 33·4	
Hall's Stream	45 01	288 30	1845.	Graham.	76 23·5	
Mount Washington	44 17	288 41	1845.	Locke.	75 45·0	
Near Mount Washington	44 16	288 31	1845.	Locke.	75 40·0	
Stanstead	45 02	287 50	1842.	Lefroy.	76 19·5	
L. Memphremagog, East shore	45 01	287 41	1845.	Whipple.	76 08·6	
Cornwall	45 02	285 13	1845.	Younghusband.	76 16·4	
Brockville	44 35	284 15	1845.	Younghusband.	76 18·9	
Penetanguishene	44 49	279 59	1844.	Lefroy.	76 20·1	
South Manitou Island	45 05	274 22	1841.	Loomis.	75 59·3	75 57·9
South Manitou Island	45 05	274 22	1842.	Younghusband.	75 56·6	

* Lieut. A. W. Whipple, of the United States Corps of Topographical Engineers. The observations at Portsmouth were made at five different stations, which are named in order of succession corresponding with the entries in the Table; Jamaica Island; near the north extremity of the base line of the Trigonometrical Survey of the harbour;

TABLE LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
			76° 30′ to 77° 30′.			
	° ′	° ′			° ′	° ′
Grand Falls of the St. John.	47 03	292 15	1843.	GRAHAM.	77 29·5	
Aroostook Hill	46 47	292 13	1841.	GRAHAM.	77 24·1	
Blue Hill...................	46 38	292 13	1841.	GRAHAM.	77 18·1	
Park's Hill	46 07	292 13	1840.	GRAHAM.	77 02·5	77 01·6
Park's Hill	46 07	292 13	1841.	GRAHAM.	77 00·7	
N.E. Boundary Station, No. 1. ..	45 57	292 13	1840.	GRAHAM.	76 57·4	
Near the Grand Forks of the St. John	46 35	290 07	1844.	GRAHAM.	77 25·9	
S.W. branch of the River St. John	46 25	289 56	1844.	GRAHAM.	77 24·7	
Moose River	45 39	289 44	1844.	GRAHAM.	76 48·5	
Taschereau's	45 49	289 36	1844.	GRAHAM.	76 50·4	
Quebec.....................	46 49	288 44	1842.	LEFROY.	77 15·3	77 12·0
Quebec.....................	46 49	288 44	1845.	YOUNGHUSBAND.	77 08·8	
Three Rivers	46 19	287 24	1842.	LEFROY.	77 10·7	
St. John's..................	45 20	287 00	1842.	LEFROY.	77 00·1	
Sorel......................	46 02	287 00	1842.	LEFROY.	77 17·0	
Rouse's Point	45 00	286 37	1845.	GRAHAM and WHIPPLE.	76 39·8	
St. Helen's	45 31	286 25	1842.	LEFROY.	77 13·1	77 09·2
St. Helen's	45 31	286 25	1843.	LEFROY.	77 05·3	
Montreal	45 30	286 24	1845.	YOUNGHUSBAND.	77 08·6	
Isle d'Urval	45 24	286 14	1843.	LEFROY.	77 21·1*	
La Combes	45 32	285 51	1843.	LEFROY.	76 50·6	
Pointe aux Chênes	45 37	285 05	1843.	LEFROY.	76 55·4	
Williamsburg	44 55	284 53	1843.	LEFROY.	76 30·1	
Fox's Point	45 32	284 26	1843.	LEFROY.	76 35·3	
Point Aylmer	45 29	284 12	1843.	LEFROY.	76 41·0	
Kingston	44 13	283 25	1842. 1843.	LEFROY.	77 18·7	77 16·5*
Kingston	44 13	283 25	1845.	YOUNGHUSBAND.	77 14·4	
Grand Calumet	45 45	283 20	1843.	LEFROY.	76 44·4	
Fort Coulange...............	45 56	283 13	1843.	LEFROY.	77 29·7	
Point Baptême...............	46 06	282 34	1843.	LEFROY.	77 26·6	
Deux Joachim's Portage........	46 12	281 41	1843.	LEFROY.	77 03·8	
Trou Portage	46 15	281 27	1843.	LEFROY.	77 24·4	
Little River	46 18	281 17	1843.	LEFROY.	77 28·5	
Lac du Grand Vase............	46 18	280 34	1843.	LEFROY.	77 21·7	
Lake Nipissing...............	46 13	280 01	1843.	LEFROY.	77 09·5	
Ricolet Falls	45 57	278 59	1843.	LEFROY.	76 45·4	
Pointe au Croix	45 55	278 42	1843.	LEFROY.	76 31·3	
Lake Huron..................	46 00	278 10	1843.	LEFROY.	77 05·6	
Fort la Cloche...............	46 07	277 35	1844.	LEFROY.	76 50·2	
Snake Island	46 07	277 00	1843.	LEFROY.	77 05·5	
Tessalon Point...............	46 16	276 29	1843.	LEFROY.	76 59·3	
Fort Brady	46 30	275 36	1841.	LOOMIS.	77 29·7	
Sault St. Mary..............	46 30	275 26	1843.	LOCKE.	77 30·3	77 24·9
Sault St. Mary..............	46 30	275 26	1845.	RAE.	77 19·5	
Mackinac....................	45 51	275 19	1841.	NICOLLET.	76 34·5	76 37·0
Mackinac....................	45 51	275 19	1841.	LOOMIS.	76 37·5	
Mackinac....................	45 51	275 19	1843.	LOCKE.	76 38·9	
Gross Cap	46 32	275 17	1841.	LOOMIS.	77 05·3	
Point aux Pins..............	46 29	275 19	1843.	LEFROY.	77 13·4	77 14·7
Point aux Pins..............	46 29	275 19	1845.	RAE.	77 16·0	
Point au Crêpe	46 58	275 02	1843.	LEFROY.	77 11·5	
Encampment	46 44	272 17	1843.	LOCKE.	76 58·3	
Houghton's River	47 28	271 59	1843.	LOCKE.	77 20·7	
United States' Agency	47 28	271 59	1843.	LOCKE.	77 13·5	
Ontanogon River.............	46 52	270 29	1843.	LOCKE.	77 13·2	
Portage Ecarté	48 25	270 15	1843.	LEFROY.	77 13·5*	
Lapointe	46 47	269 02	1843.	LOCKE.	76 56·0	

Table LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
	77° 30′ to 78° 30′.					
	° ′	° ′			° ′	° ′
North bank of the St. John River	47 04	292 13	1843.	Graham.	77 31·1	
Peconk Hill	46 59	292 13	1841.	Graham.	77 32·2	
Mouth of the Grand River	47 11	292 03	1844.	Graham.	77 38·4	
Mouth of the Madawaska	47 22	291 41	1843.	Graham.	77 47·5	
Albert's Inn	47 17	291 32	1843.	Graham.	77 44·5	
Fort Kent	47 15	291 25	1843.	Graham.	77 43·1	
St. Francis River	47 11	291 06	1843.	Graham and Robinson*.	77 43·5	
Head of Beau Lac	47 23	290 57	1843.	Graham.	77 47·0	
Mouth of the Passa-ooe-tuc.	47 07	290 55	1844.	Graham.	77 40·5	
Outlet of Lake Pohenagamook	47 28	290 47	1843.	Graham.	77 49·2	
M. of the Chimpassaooetuc	46 57	290 33	1843.	Graham.	77 37·5	
Kingsey	45 48	287 41	1842.	Lefroy.	77 40·0†	
Fort Michipicoton	47 56	274 55	1843.	Lefroy.	78 06·0	78 06·
Fort Michipicoton	47 56	274 55	1844.	Lefroy.	78 08·2	
Fort Michipicoton	47 56	274 55	1845.	Rae.	78 05·0	
Gargantua	47 37	274 49	1844.	Lefroy.	77 56·1	
Lake Superior	48 46	272 20	1844.	Lefroy.	78 24·0	
Isthmus	47 28	272 00	1843.	Locke.	78 28·0†	
Eagle River	47 27	271 37	1843.	Locke.	77 54·5†	
Isle Royale	48 06	271 13	1843.	Locke.	78 07·5	
Pointe Tonnerre	48 19	270 58	1843.	Lefroy.	78 23·2	
Fort William	48 24	270 37	1843.	Lefroy.	78 10·0	78 06·
Fort William	48 24	270 37	1844.	Lefroy.	77 59·5	
Fort William	48 24	270 37	1845.	Rae.	78 11·0	
Chien Portage	48 39	270 26	1843.	Lefroy.	78 26·8	
Prairie Portage	48 58	269 59	1843.	Lefroy.	78 26·2	
Savannah Portage	48 53	269 52	1843.	Lefroy.	78 21·8	
French Portage	48 35	268 53	1843.	Lefroy.	78 20·4	
Deux Rivières Portage	48 35	268 33	1843.	Lefroy.	77 49·4	
Lac à la Crosse	48 24	267 50	1843.	Lefroy.	77 51·0	
Second Portage from Lac à la Crosse	48 15	267 33	1843.	Lefroy.	77 40·1	
Sturgeon Lake	48 27	267 19	1843.	Lefroy.	77 44·8	
Lac la Pluie	48 32	267 04	1843.	Lefroy.	77 47·9	
Fort Francis	48 37	266 31	1843.	Lefroy.	77 27·5	77 34·
Fort Francis	48 37	266 31	1844.	Lefroy.	77 43·0	
Fort Francis	48 37	266 31	1845.	Rae.	77 32·0	
Rainy River	48 48	265 29	1843.	Lefroy.	77 57·4	
Rat Portage	49 46	265 21	1843.	Lefroy.	78 07·5	
Lake of the Woods	49 28	265 20	1843.	Lefroy.	78 16·7	
Lake of the Woods	49 19	265 18	1843.	Lefroy.	78 03·7	
Upper Fort Garry	49 53	262 58	1843.	Lefroy.	78 17·8	
Saskatchawan River	52 23	252 56	1844.	Lefroy.	78 16·6	
Saskatchawan River	53 07	251 30	1844.	Lefroy.	78 28·1	
Saskatchawan River	54 05	248 16	1844.	Lefroy.	78 05·2	
Fort Edmonton	53 31	247 03	1844.	Lefroy.	77 54·2	
Pembina River	54 08	246 06	1844.	Lefroy.	77 54·5	
Fort Assiniboine	54 20	245 32	1844.	Lefroy.	78 15·2	
Point Dejala	55 26	244 59	1844.	Lefroy.	78 29·9	
	78° 30′ to 79° 30′.					
White River	48 33	273 33	1844.	Lefroy.	78 33·1	
Fort Pie	48 38	273 21	1843.	Lefroy.	78 45·8	78 37·1
Fort Pie	48 38	273 21	1844.	Lefroy.	78 31·5	
Fort Pie	48 38	273 21	1845.	Rae.	78 34·0	

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* Captain William Robinson, Royal British Engineers, attached to the Survey and Boundary Commissio

† Local disturbance,—omitted in the map.

Table LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.	
	78° 30′ to 79° 30′.					
	° ′	° ′			° ′	° ′
Terreplatte	48 40	272 15	1843.	Lefroy.	78 53·6	
Magnetic Inlet	47 28	271 59	1843.	Locke.	78 44·3*	
500 feet East of Ditto	47 28	271 59	1843.	Locke.	78 37·5*	
Slave Portage	50 11	264 23	1843.	Lefroy.	78 57·1	
Fort Alexander	50 37	263 39	1843.	Lefroy.	78 51·8	78 57·4
Fort Alexander	50 37	263 39	1844.	Lefroy.	79 03·0	
Lake Winnipeg	50 27	263 22	1843.	Lefroy.	79 05·2	
Lake Winnipeg	51 34	263 20	1844.	Lefroy.	79 06·1	
Mouth of Red River	50 19	263 15	1843.	Lefroy.	78 32·6	
Lake Winnipeg	51 04	263 15	1843.	Lefroy.	79 11·8	
Lake Winnipeg	51 45	263 07	1843.	Lefroy.	79 28·3	
Saskatchawan River	53 16	255 12	1844.	Lefroy.	79 11·2	
Carlton House	52 51	253 47	1844.	Lefroy.	78 30·7	
Fort Pitt	53 34	250 41	1844.	Lefroy.	78 41·0	
Saskatchawan River	53 50	249 30	1844.	Lefroy.	78 33·5	
Forks of Athabasca River	55 13	246 10	1844.	Lefroy.	78 55·2	
Athabasca River	54 43	246 00	1844.	Lefroy.	78 34·1	
Lesser Slave Lake	55 33	244 07	1844.	Lefroy.	78 39·0	
Peace River	57 19	243 32	1844.	Lefroy.	79 27·0	
Opposite River Cadotte	56 47	242 58	1844.	Lefroy.	79 20·7	
Fort Dunvegan	55 56	241 26	1844.	Lefroy.	78 46·2	
	79° 30′ to 80° 30′.					
Otter Island	48 06	273 43	1843.	Lefroy.	79 43·6*	
Lake Winnipeg	51 04	263 39	1844.	Lefroy.	79 31·5	
Lake Winnipeg	51 44	263 12	1844.	Lefroy.	79 39·0	
Lake Winnipeg	51 38	263 11	1843.	Lefroy.	79 38·0	
Lake Winnipeg	52 21	262 51	1844.	Lefroy.	80 24·4	
Lake Winnipeg	52 29	262 47	1843.	Lefroy.	80 05·4	
Lake Winnipeg	53 31	260 48	1843.	Lefroy.	80 16·8	
Grand Rapid	53 08	260 32	1843.	Lefroy.	80 21·5	80 26·5
Grand Rapid	53 08	260 32	1844.	Lefroy.	80 31·6	
Cross Lake	53 10	260 28	1843.	Lefroy.	80 28·2	
Cedar Lake	53 12	259 30	1843.	Lefroy.	80 07·1	
Devil's Drum Island	53 19	259 20	1844.	Lefroy.	80 00·0	
Above the Pas	53 48	258 32	1844.	Lefroy.	80 24·4	
Cumberland House	53 57	257 41	1843.	Lefroy.	80 30·2	80 24·9
Cumberland House	53 57	257 41	1844.	Lefroy.	80 19·7	
Little Rock Portage	55 34	255 27	1843.	Lefroy.	80 16·5	
Portage Sonnante	55 54	252 13	1843.	Lefroy.	80 11·2	
Isle à la Crosse	55 27	252 06	1843.	Lefroy.	80 09·8	
Buffaloe Lake	56 05	251 09	1843.	Lefroy.	80 37·0	
River de la Loche	56 15	250 37	1843.	Lefroy.	80 19·7	
Peace River	57 57	243 00	1844.	Lefroy.	80 00·7	
	80° 30′ to 81° 30′.					
Lake Winnipeg	52 23	263 07	1843.	Lefroy.	80 39·2	
Hairy Lake	54 21	262 49	1843.	Lefroy.	81 20·9	
Old Norway House	53 42	261 59	1843.	Lefroy.	80 45·4	
Norway House	53 59	261 53	1843.	Lefroy.	81 08·9	81 10·0
Norway House	53 59	261 53	1844.	Lefroy.	81 11·2	
Beaver Lake	54 32	257 50	1843.	Lefroy.	80 34·2	
Carp Portage	54 47	257 21	1843.	Lefroy.	80 39·6	
Portage des Epinettes	55 06	257 18	1843.	Lefroy.	80 52·6	
Frog Portage	55 28	256 30	1843.	Lefroy.	80 59·3	
Great Devil's Portage	55 40	255 11	1843.	Lefroy.	80 30·9	

TABLE LI. (Continued.)

Station.	Lat.	Long.	Year.	Observer.	Inclination.
	80° 30′ to 81° 30′ (continued).				
	° ′	° ′			° ′
Pine Portage	55 43	254 10	1843.	LEFROY.	80 40·3
Snake Rapid	55 46	253 30	1843.	LEFROY.	80 38·7
Portage de la Loche, South end	56 34	250 16	1843.	LEFROY.	80 36·4
Portage de la Loche, North end	56 43	250 08	1843.	LEFROY.	80 38·0
Clearwater River	56 39	249 11	1843.	LEFROY.	80 36·2
Pierre au Calumet	57 24	248 25	1843.	LEFROY.	81 16·8*
Poplar Island	58 38	246 03	1844.	LEFROY.	81 04·8
Falls of Peace River	58 24	245 06	1844.	LEFROY.	80 50·8
Fort Vermilion	58 25	243 45	1844.	LEFROY.	80 48·0
	81° 30′ to 82° 30′.				
Long Portage	55 15	265 35	1843.	LEFROY.	82 13·9
Windy Lake	54 37	263 58	1843.	LEFROY.	81 57·0
Whitefall Portage	54 24	263 34	1843.	LEFROY.	81 47·9
Athabasca	58 43	248 42	1843.	LEFROY.	81 37·0
Pointe Brulée	58 07	248 35	1843.	LEFROY.	81 30·6
Pelican Portage	59 58	248 09	1844.	LEFROY.	82 26·8
Point Providence	58 58	247 50	1844.	LEFROY.	81 46·1
Peace River	58 58	247 01	1844.	LEFROY.	81 36·9
Big Island	61 12	243 22	1844.	LEFROY.	82 08·7
Fort Simpson	61 51	238 35	1844.	LEFROY.	81 52·3
	82° 30′ to 83° 30′.				
White Earth Portage	55 32	266 10	1843.	LEFROY.	83 02·9
Hill River	55 25	266 00	1843.	LEFROY.	82 55·0
Oxford House	54 56	264 30	1843.	LEFROY.	82 38·8
Portage Grand Detour	60 22	247 00	1844.	LEFROY.	82 33·6
Fort Resolution	61 10	246 15	1844.	LEFROY.	82 44·5
Fort Norman	64 31	235 16	1844.	LEFROY.	82 34·3
Fort Good Hope	66 16	231 30	1844.	LEFROY.	82 56·0
	83° 30′ to 84° 30′.				
York Factory	57 00	267 34	1843.	LEFROY.	83 47·2
Shamatawa	56 21	267 04	1843.	LEFROY.	83 36·2

* Local disturbance; omitted in the map.

XVIII. *Contributions to Terrestrial Magnetism.—No. VIII.*

By Lieut.-Colonel Edward Sabine, *R.A., For. Sec. R.S.*

Received June 15,—Read June 18, 1846.

Containing a Magnetic Survey of the Southern Hemisphere between the Meridians of 0° and 125° East, and Parallels of −20° and −70°.

THE Antarctic Expedition, under Captain Sir James Clark Ross, R.N., has furnished the materials for maps of the three magnetic elements in the high latitudes of the southern hemisphere for nearly two-thirds of its circumference. The first and second portions of the results, comprising between the meridians of 125° and 300°, have already been communicated to the Royal Society, and are contained in the Vth and VIth Numbers of these Contributions*; a third portion, comprehending between the meridians of 300° and 360°, is in preparation and will shortly be laid before the Society. In order to complete the magnetic survey of the high latitudes of the southern hemisphere as far as they are accessible, there remained the portion between the longitudes of 0° and 125°, or thereabouts. The tracks of vessels in the employ of the enterprising merchants, the Messrs. Enderby, had shown that no difficulties of serious importance obstructed the navigation of the ocean in the vicinity of the Antarctic Circle between the meridians specified: and there appeared to be little reason to doubt, that a vessel, despatched from the Cape of Good Hope, might accomplish this remaining portion of the survey in a single season, without encountering any particular risk.

Lieut. Clerk, of the Royal Artillery, had been attached by Lord Vivian, Master-General of the Ordnance, to the Magnetic Observatory at the Cape of Good Hope, with the express view of being engaged in a magnetic survey, either of the colony itself, or of such portion of the globe as might be conveniently accessible from it; and on his passage from England to the Cape had had an opportunity of practising with the instruments employed in a magnetic survey conducted on the ocean. The completion of the survey of the high latitudes appeared the most important service which Lieut. Clerk could render to magnetical science; and on its being proposed to him, he most readily undertook it.

In June 1844 the subject was brought under the consideration of the Committee of Physics of the Royal Society, by a letter from myself to Sir John F. W. Herschel, Bart., Chairman of the Committee, accompanied by one addressed by Sir John Herschel to the Committee, expressing his earnest hope that the measures suggested for the completion of the survey might receive the attention which they appeared to him to merit. These letters were submitted by the Committee to the Council of the Royal Society, with a recommendation that an application should be made by the President and Council to the Lords Commissioners of the Admiralty, to authorize the completion of the southern survey in the manner suggested.

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* Philosophical Transactions, 1843, Art. X., and 1844, Art. VII.

The Board of Admiralty having been pleased to accede to this request, the "Pagoda," a bark of 360 tons, was hired at the Cape of Good Hope by the Admiral commanding on the station, and was fitted for a voyage of some months duration, receiving a complement of four officers and thirty-eight seamen from the flag-ship. Lieut. T. E. L. Moore, of the Royal Navy, who had been one of the officers of Her Majesty's ship Terror in the Antarctic Expedition, and was consequently accustomed to the navigation of the high latitudes, as well as practised in magnetic observations, (having taken a very prominent share in those of Her Majesty's ship Terror, recorded in Nos. V. and VI. of these Contributions,) was selected to command the Pagoda, and instructed to cooperate with Lieut. Clerk, and to give him every assistance and support in the execution of the service on which they were jointly employed. At the time of his appointment, Lieut. Moore was serving in the Caledonia at Lisbon, and some little delay occurred in his recall, and also in his subsequent departure from England, in consequence of which he did not join the Pagoda at the Cape until the 4th of January, when she had been some days ready for sea.

It may be useful to officers desirous of making magnetic observations on board ship, to be acquainted with the precautions which, at the period in question, were deemed desirable for the employment of magnetic instruments on board ship under the most advantageous conditions, and for eliminating the disturbing effects of the ship's iron: a copy of the instructions with which Lieut. Clerk was furnished is therefore subjoined:—

Instructions for Lieut. H. Clerk, *R.A., on points connected with the Magnetic Observations on Board Ship.*

"1. *Influence of the Ship's Iron.*—Before the ship is fitted, you had better select, in concert with the naval officer appointed to command her, suitable positions for the standard compass and for your Fox. They should both be on the midship line of the ship; the standard compass sufficiently high to see well over the bulwarks when taking azimuths; the Fox lower for the sake of steadiness: it is generally found convenient to use the Fox a few feet in front of the standard. When the positions have been chosen, have any iron that may be near them removed, (as far as can conveniently be done,) and do not let any fresh iron be placed within at least six feet of either of them.

"When the ship is perfectly ready for sea, take a day for the determination of the effect of the ship's iron on the standard compass. You are already acquainted with the usual process of doing this, and are furnished with the printed instructions issued by the Admiralty; therefore I do not enter into further details on this point, except to suggest that you should be particularly careful that the ship's boats, davits, &c. are all in the positions they will occupy at sea; and that it will be quite sufficient for your purpose that the deviation should be tried on the sixteen principal points of the compass, instead of on thirty-two, as is sometimes done.

"2. Whilst engaged with the standard compass, have a second compass, of which the compass error (meaning thereby the index error) is known, placed in the gimball table of your Fox, and observe generally (by means of the lubber-line) whether the effect of the ship's iron is nearly the same at the two positions, viz. at the position of the standard compass and at that of the Fox. Observe particularly whether the points of no deviation are the same. It simplifies matters greatly that they should be so, and that at both positions the points of no deviation should be nearly the north and south points. This they will most probably be in a vessel which will not have much iron near either position; but it will be advantageous, when first choosing the positions, to try roughly,—by means of a couple of compasses, one in the proposed position of the standard compass, and the other in that of the Fox,—whether they point alike when the ship's head is either north or south. By interchanging the compasses in these positions, you will prevent any deception which might arise from compass errors.

"The observations which have been described will give you the value of the constants *a* and *b*, for the corrections of all the declinations observed on board throughout the voyage, and you will probably find that they will give you work enough for one day.

"3. I shall suppose therefore that you take a second day for the determination of the four constants at the position of the Fox. For this you will require the inclination and intensity with the ship's head on the same sixteen points as before, employing a deflector for the intensity on this occasion, in preference to weights, as more convenient. You will find of course that the points of no deviation with the compass become the points of extreme deviation of the inclination and intensity; for convenience I shall suppose them north and south points. Having completed the observations with the Fox, remove it and observe the horizontal intensity with the head successively north, east, south and west, and north again[*], placing the apparatus for the horizontal intensity on the gimball stand of the Fox. This will give you *a* and *b* for that position more satisfactorily than the observations of the Fox; from these latter, with the shore observations, you will have *c* and *d*.

"The formulæ applicable to all the proceedings which have been described, will be found in Mr. SMITH's Memorandum in No. V. of the Contributions to Terrestrial Magnetism. But besides the induced magnetism to which these formulæ refer, the iron of a ship is found sometimes to exercise upon its compasses a magnetic influence of a distinct character, to which it may become in some instances desirable to give a separate consideration. This influence may be either from permanent magnetism strictly so called, or from a polarity which is temporarily retained, and undergoes alterations consequent upon changes in the inducing action in which it originated, but following after them at a greater or less interval of time. This additional magnetic force may be represented by additional symbols, P, Q and R, *i. e.* the force resolved along the principal section of the ship, transversely to it, and in the vertical direction.

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[*] These are compass points, the compass being supposed in strictness to be placed on the spot of the gimball table; if a compass placed at this spot has been found to agree with the standard compass, the latter gives directly the required azimuth of the ship's head.

"The alterations which the introduction of this force makes in Mr. SMITH's formula are stated in a second memorandum now printing in No. VI. of the Contributions, a copy of which will be in your hands before you sail.

"This memorandum furnishes equations by which all the constants may be determined by observations in different magnetic latitudes,—of the horizontal force on the *four* principal points,—and of the dip on the *two* principal, together with the dip and horizontal force observed on shore or on the ice. These are part of the observations already directed.

"4. The observations described in No. 3 must be repeated on the return to the Cape at the conclusion of the voyage, before any change has been made in the iron of the ship. If polarity due to the inducing action of a higher magnetic latitude has been retained, the observations on the return will be found to differ from those made before you sailed. If the disturbing influence of the ship's iron be solely the effect either of instantly induced magnetism, or of permanent magnetism strictly so called, the observations will agree with those made before the departure of the vessel.

"5. If in the course of the voyage you should anchor in any port in a high latitude, at Enderby's Land for example, or at the Adelie Land of d'Urville, it will be extremely desirable to repeat the same observations. Whenever a choice exists between the shore and fixed ice, as a place for observation out of the influence of the ship's iron, always prefer the fixed ice.

"6. The approximate value of a, the most important of the constants, may be obtained on board at any time during the voyage when the weather is sufficiently favourable, by azimuths at the north or south points and at the east or west points for the position of the standard compass, and by the horizontal intensity observed on the north and south points for the position of the Fox. If HANSTEEN's needles are used for the latter purpose, and n, s, be the number of vibrations at north and south in a certain time, commencing at the same arc, and performed in a nearly uniform temperature, then $\frac{n}{s} = \tan \lambda$, and $\cos 2\lambda = a \tan \theta$; also if $\Delta =$ the deviation when $\zeta = 90°$,

$$\Delta = 90° - 2\lambda.$$

"7. The horizontal intensity at the north and south points should be observed on board *frequently*; those on the north, south, east and west points, *occasionally*; and the dip and horizontal intensity on shore or on the ice, with corresponding observations on board, as *often as possible*.

"8. *Index Correction.*—The most convenient mode of employing Mr. Fox's apparatus at sea being to use it with the face of the circle in one direction only (*i. e.* east or west, I shall here assume it *east*), the index correction with the face east must be sought, by a comparison of the Inclinations observed in that position of the instrument on shore and on fixed ice, with the true Inclinations determined with needles whose poles may be reversed and a complete observation made with them. As the index correction is liable to vary as a function of the Inclination, it should be determined in different Inclinations, and for this purpose it will be desirable to obtain at least one determination in a high latitude.

"When observing *on shore* or *on the ice* for the index correction with the face east, do not omit to observe with the face west also, as the mean index correction is useful in showing the kind of separation which exists between the centre of gravity and the point of suspension in the needle for which it is determined. Mr. Fox's apparatus is furnished with three needles; one to be used when the poles are required to be reversed; the magnetism of the other two should be preserved from change if possible; it has been found a convenient practice to employ one of the latter always as the mounted needle, and the other as a deflector.

"9. *Comparison of the Weights and Deflectors.*—Experience has shown that the intensity may be more conveniently and satisfactorily determined on board ship by the use of deflectors than by constant weights.

"It is necessary however that the 'equivalent weights' of the deflectors employed should be carefully ascertained. Besides the table which you will form for this purpose in the manner practised by Mr. Fox, it will be necessary to have comparisons between the angles of deflection produced by the deflectors and the constant weights at the Cape before and after the voyage, and on any opportunity which you may have in a high latitude either on shore or on the ice. You may also get occasional comparisons *on board* in very favourable weather.

"In the choice of constant weights to be employed during the voyage, use none that give a less angle of deflection than 15°. In the observations at the Cape, as your base station, make a double series (*i. e.* the same observations repeated on two separate days) both *before and after* the voyage.

"10. *Azimuths.*—You will find it a convenient practice to deduce your azimuths from the *hour angle*, instead of from the altitude, which is the more usual custom. First take the altitudes which will give you the hour angle corresponding to the time by chronometer (at least until you *materially* change your geographical position); and as soon as you have completed this observation, take the sun's azimuth, noting the time of observation by chronometer; the hour angle will then give you the true azimuth. Blank forms are sent suited to this mode of observation.

"11. *General Remarks.*—You cannot do better than follow the admirable example of the Antarctic Expedition, in observing the three magnetic elements on board every day on which the weather will permit you to use the instruments.

"12. Frequent reference has been made in these instructions to the importance of at least one opportunity of observing on shore or on the ice in a high latitude, for various objects connected with the reduction and correction of the whole body of magnetic observations made during the voyage. If Enderby's Land, or land connected with it, should not be accessible, it is by no means necessary that the ship should *enter* the ice in order to give you the opportunity of landing on a piece of ice of sufficient magnitude. A favourable day being chosen, she may approach the ice sufficiently near, and remain four or five hours, whilst her boat takes you to make the observations and to return.

"If the ice be not 'fixed' you must be careful to detect an azimuthal motion, should there be any, by which the inclination circle might otherwise be removed from the plane of the magnetic meridian without your being aware of it. You will also take care that the magnetic instruments are sufficiently distant from the boat.

"EDWARD SABINE."

"*Woolwich.*"

The Pagoda sailed from the Cape of Good Hope on the 9th of January, proceeding, pursuant to instructions, towards the Antarctic Circle in the meridian of Greenwich. She crossed the 60th parallel in the longitude of 4° east, and being impeded by ice in her direct progress to the southward, coasted its margin to the south-east, and attained her greatest southing on the 10th of February in latitude $-68° 10'$ and longitude 35°. She was then according to the chart in the vicinity of the western extremity of Enderby's Land, but from strong south-east gales and the position of the ice was unable to approach it sufficiently even to see the land: from thence she continued a general progress to the eastward, keeping in as high a parallel as the ice and weather permitted. On the 10th of March she had obtained the 96th degree of east longitude in about the 60th degree of latitude, when the season was considered to be so far advanced that it would not be prudent to persevere in the completion of the survey in the high latitudes; and a course was therefore taken for King George's Sound in Australia, where the ship arrived on the 1st of April. During the whole of this voyage observations of the three magnetic elements were made twice in each day, except in extreme circumstances of weather, by Lieut. MOORE in the afternoon and Lieut. CLERK in the forenoon, each being furnished with a separate (Fox's) apparatus for the Inclination and Force; and on the arrival of the ship at King George's Sound, the two instruments were found to give an almost identical value for the intensity of the force, the results being by Lieut. MOORE's Fox 1·680, and by Lieut. CLERK's 1·688.

After remaining a sufficient time to examine the index and other corrections of the instruments, and to obtain the necessary data for eliminating the effects of the ship's iron on the magnetic results obtained during the voyage, the Pagoda quitted King George's Sound on the 27th of April and returned to the Cape of Good Hope, touching at Mauritius by the way for the purpose of repeating the observations on the influence of the ship's iron. She arrived at the Cape on the 20th of June, having continued the practice of observing the magnetic elements daily on the return passage, in the same manner as in the high latitudes.

The voyage was performed without accident or loss of life, and the crew returned in perfect health, due doubtless in great degree to the supplies of warm clothing and preserved meats, which, by direction of the Admiralty, Lieut. Moore had taken with him from England.

No failure occurred in any of the instruments notwithstanding the continual use in which they were kept by the zeal of the observers. If where so much was so well accomplished it is permissible to feel or to express regret on any account, it can be only that circumstances should have prevented the completion of the survey in the high latitudes as far as the 125th degree of longitude according to the original design, whereby the observations of the magnetic force would have been carried up to the principal axis of the isodynamic oval of 2·00.

On the conclusion of the voyage Lieut. Clerk received directions from the Master-General of the Ordnance to return to Woolwich, for the purpose of completing the reduction of his own observations and those of Lieut. Moore. The following pages contain Lieut. Clerk's report; in which he has also embodied a series of observations on the Inclination and Force with a Fox's apparatus, made in 1844 by Lieut. Alexander Smith, R.N., one of the Assistants at the Hobarton Magnetic Observatory, on his passage to Van Diemen Island; and a second series, also of the Inclination and Force, made in 1845 by Lieut. Dayman, R.N., of the same observatory, in a passage in the bark "Leander" from Hobarton to the Cape. Both these officers had previously been employed in the Antarctic Expedition under Sir James Clark Ross, and their observations now communicated are a consequence of the zeal which they imbibed, and the practice in the use of instruments which they acquired, in that expedition. Their observations transmitted to the Admiralty were sent to Woolwich for reduction and publication. Lieut. Clerk has also embodied in his report the determinations of the three magnetic elements made by Sir James Ross in the Erebus in 1840 on her passage from the Cape of Good Hope to Kerguelen Island, and thence to Hobarton.

On inspecting the map, it will be seen that the tracks of the Erebus and Prince Regent held about a middle line between the outward and homeward tracks of the Pagoda, and are therefore extremely useful in connecting results which would otherwise have been somewhat too far apart.

Lieut. Clerk has taken the Cape of Good Hope as the base station of the observations of the magnetic force made in the Pagoda. The determinations of the absolute horizontal force made at the observatory at the Cape in February, March, April and

May 1845 (page 362 *in seq.*), which are the last received from that station, give a mean result of 4·482, the mean inclination during the same month being $-53^{\circ}\,25'\cdot5$. Combining these with the determination at Woolwich in No. VII. of these Contributions[*], we have the total force at the Cape in the arbitrary scale 0·993. The ratios determined by Mr. Fox's statical apparatus (page 363 *in seq.*) by separate needles are 1·000 and 1·006: the value of the total force at the Cape as a base station for the observations of the Pagoda has therefore been taken as 1·000.

As Lieut. Smith did not touch at the Cape on his passage to Hobarton, and as the needle which Lieut. Dayman had employed on his homeward passage was broken at the Cape before observations had been made with it, and consequently before the series between Hobarton and the Cape could be connected with the latter station, it has been necessary to employ Hobarton as the base station of both these series. I have already stated in Nos. V. and VI. of these Contributions, the results of the observations which were made to determine the absolute horizontal force at Hobarton between 1840 and 1844; viz. by Sir James C. Ross in 1840 and 1841, with magnets of fifteen inches in length[†]; by Lieut. Kay in 1841 and 1842, with magnets of the same length[‡]; by Lieut. Kay in 1844 with magnets of twelve inches[§], and with others of 9·18 and 7·50 inches[‖]. I have now to add the results of twenty-four determinations made by Lieut. Kay between November 1844 and September 1845, with magnets of various lengths, as shown in the following table:—

Magnets and their length.		Date.	No. of distances.	Horizontal force.
Suspended.	Deflecting.			
in.	in.			
—— 7·50	—— 9·18	Nov. 7, 1844.	3	4·5108
—— 7·50	—— 9·18	Sept. 9, 1845.	3	4·4810
A 57 3·00	D xv. 3·67	Dec. 7, 1844.	3	4·5316
A 57 3·00	D xv. 3·67	Dec. 9, 1844.	5	4·5118
A 57 3·00	D xv. 3·67	Dec. 11, 1844.	5	4·4954
A 57 3·00	D xv. 3·67	Jan. 12, 1845.	5	4·5058
A 57 3·00	D xv. 3·67	May 5, 1845.	3	4·4997
A 57 3·00	D xv. 3·67	Aug. 15, 1845.	5	4·4762
A 57 3·00	D 9 3·67	Aug. 19, 1845.	5	4·5104
A 57 3·00	D 9 3·67	May 6, 1845.	3	4·5076
A 57 3·00	A 19 3·02	Aug. 20, 1845.	5	4·4905
A 52 3·00	D xvi. 3·67	Jan. 19, 1845.	3	4·4940
R 1 3·00	D xvi. 3·67	Aug. 28, 1845.	4	4·4970
I 12 2·45	A 19 3·00	Dec. 13, 1844.	5	4·4954
I 12 2·45	A 19 3·00	Dec. 13, 1844.	5	4·4899
I 12 2·45	A 19 3·00	Dec. 15, 1844.	5	4·4865
I 12 2·45	A 19 3·00	Jan. 14, 1845.	5	4·4809
I 12 2·45	A 29 3·00	Aug. 26, 1845.	5	4·5016
I 12 2·45	A 23 3·00	Aug. 22, 1845.	5	4·4994
I 1 2·45	A 23 3·00	Dec. 20, 1844.	3	4·5046
I 1 2·45	A 23 3·00	Dec. 23, 1844.	3	4·5121
I 1 2·45	A 23 3·00	Dec. 26, 1844.	5	4·5020
I 1 2·45	A 23 3·00	Jan. 15, 1845.	5	4·5082
I 1 2·45	A 23 3·00	May 9, 1845.	3	4·4970
		Mean.....................		4·4992

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[*] Philosophical Transactions, 1846, p. 246.

[†] Ibid. 1843, p. 168.

[‡] Ibid. p. 168 (note).

[§] Ibid. 1844, p. 111.

[‖] Ibid. p. 112.

Collecting in one view the different mean results, we have

Ross, in 1840–41, 15 in. magnets	4·573
Kay, in 1841, 15 in. magnets	4·553
Kay, in 1842, 15 in. magnets	4·513
Kay, in 1843, 12 in. magnets	4·520
Kay, in 1843, 9·18 and 7·50 in. magnets	4·501
Kay, in 1844–45, magnets of various lengths, 9·18 to 2·45 in.	4·499

These results exhibit (with one exception) a progressive decrease, but between those of 1840–41, and subsequent years, there is a very great difference. The inclination has decreased from −70° 40′·7, observed in 1840–41*, to −70° 37′·6, which is the mean of the results obtained twice in each week at the Hobarton Observatory in the first nine months of 1845. Assuming the total force at Hobarton as constant, the horizontal component should have been increased rather than diminished by the small secular change which appears to have taken place in the Inclination. The discrepancy between the earlier and later results of the absolute determinations cannot therefore be a consequence of secular change in the Inclination; nor is it probable that the total force should have undergone a decrease of such magnitude. Presuming the results of 1840–41, with the 15-inch magnets, to have been affected with error from some cause as yet unexplained, (possibly from an erroneous value having been taken for the moment of inertia of the magnet,) the subsequent results exhibit only such differences as cannot be regarded as excessive. They have all to undergo recalculation, as Lieut. Kay does not consider the elements of reduction as yet finally determined; and they will all, in common with all the other determinations of the absolute horizontal force given in these Contributions, have to receive a small correction for the difference of the magnetic moment of the deflecting bar, caused by the earth's inducing action in the different positions in which the bar is placed in the experiments of deflection and vibration. If, therefore, we assume provisionally the mean of the four last results, or 4·508, as the best approximation to which we have yet arrived for the horizontal component at Hobarton, and −70° 39′ as the corresponding Inclination, we have the total force in the arbitrary scale 1·797; and we may hence conclude, that influenced by the earlier determinations (those of 1840–41), the provisional value of the total force at Hobarton, employed in the Vth and VIth Numbers of the Contributions (1·82), was taken too high, and that all the values of the force dependent on Hobarton will require a correction to be applied, in amount about −0·02, before they are combined in the general map of the southern hemisphere. For Lieut. Smith's and Lieut. Dayman's observations, Lieut. Clerk has taken a base value of 1·80 at Hobarton.

A subsequent number of these Contributions will contain the Magnetic Observations of the Erebus and Terror in the summer of 1843–1844, between the meridians of Cape Horn and of the Cape of Good Hope, which will complete the survey of the high latitudes of the southern hemisphere.

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* Philosophical Transactions, 1843, p. 165.

I propose then to combine in one general view the several portions of the southern survey which have been successively communicated; and I shall reserve until that occasion, as more convenient than the present, such general remarks as suggest themselves in reference to the magnetic lines determined in the present Number.

"*Report on the Magnetic Observations made in Her Majesty's hired bark Pagoda, from January to June* 1845, *by Lieut.* HENRY CLERK *of the Royal Artillery.*

"1. *Calculation of Corrections for the Ship's Local Attraction.*

"To obtain the corrections for the observations of the Declination, the deviations of the compass were observed on each of the sixteen principal points at the Cape of Good Hope, King George's Sound, the Mauritius, and again at the Cape on the return of the Expedition. The following are the observations:—

Ship's head.	Cape of Good Hope.		King George's Sound.	Mauritius.
	January.	June.		
N.	0° 12'+	0° 20'+	0° 15'+	0° 20'+
N.N.W.	0 57+	Not observed.	0 00	0 30+
N.W.	0 08−	0 50+	0 20+	0 20−
W.N.W.	0 00	0 50−	1 40−	0 30−
W.	0 13−	0 15−	1 40−	0 50−
W.S.W.	0 28−	0 30−	1 50−	1 10−
S.W.	1 28−	1 20−	1 00−	1 10−
S.S.W.	1 06−	1 25−	0 15−	0 50−
S.	*1 48+	0 18−	0 50+	0 20+
S.S.E.	0 42+	Not observed.	0 55+	1 00+
S.E.	1 12+	1 50+	2 20+	1 20+
E.S.E.	1 27+	1 40+	3 10+	0 55+
E.	0 57+	1 45+	2 40+	1 20+
E.N.E.	0 27+	1 50+	3 10+	0 50+
N.E.	0 12+	1 35+	3 30+	1 20+
N.N.E.	0 32+	1 13+	2 35+	1 20+

The + sign denotes a deviation of the north end towards the west.

"The values of θ (the Inclination) being as follows, viz.—

Cape of Good Hope . . . . $\theta = -53^\circ\ 44'$
King George's Sound . . . . $\theta = -65\ 04$
Mauritius . . . . $\theta = -53\ 56$

"From these observations we can obtain the values of a and b by the formulæ in No. V. of the Contributions to Terrestrial Magnetism †, which give the following values, viz.—

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* This observation is evidently erroneous.

† Philosophical Transactions, 1843, Part II. p. 148.

Cape of Good Hope	$a = \cdot 0148$	$b = \cdot 9848$
King George's Sound	$a = \cdot 0199$	$b = 1 \cdot 0040$
Mauritius	$a = \cdot 0158$	$b = \cdot 9907$
Mean	$a = \cdot 0168$	$b = \cdot 9932$

"The values of a and b can also be obtained by observations of the horizontal intensity on the N., S., E. and W. points alone.

"If the card of the azimuth compass be deflected by another magnet (the small deflectors belonging to the dipping-needle for instance), and if v_n, v_s, v_w, and v_e be the angles of deflection observed on the N., S., W. and E. points respectively, then

$$a \tan \theta = \frac{\operatorname{cosec} v_n - \operatorname{cosec} v_s}{\operatorname{cosec} v_n + \operatorname{cosec} v_s}; \quad b = \frac{\operatorname{cosec} v_w + \operatorname{cosec} v_e}{2\sqrt{\operatorname{cosec} v_w \, . \, \operatorname{cosec} v_e}}.$$

"The deflections were obtained in this manner at the Cape of Good Hope, and at King George's Sound on the N. and S. points, viz.—

Cape of Good Hope.		King George's Sound.	
At N. the deflection	$=16^\circ\ 20'$	At N. the deflection	$=15^\circ\ 23'$
At S.	$=15\ \ 35$	At S.	$=14\ \ 06$
Hence	$a = \cdot 0168$	And	$a = \cdot 0198$

Agreeing very closely with the values determined above.

"After an inspection of the observations at the several stations, Mr. ARCHIBALD SMITH has kindly furnished the following Memorandum.

"'The formulæ for the correction of observations of magnetic declination, made on board ship, given in the Vth and VIth numbers of the Contributions, are deduced on the supposition that the soft iron of the ship is symmetrically distributed on each side of the fore and aft vertical section passing through the compass. The deviations observed in the Pagoda by Lieut. CLERK, seem to show that the soft iron was not so distributed in that vessel, and to require for their correction formulæ in which no supposition is made as to the distribution of the iron of the vessel, except that there is no iron very near the compass.

"'Using the notation of the memorandums in Nos. V. and VI. of the Contributions, let ϕ represent the total magnetic force of the earth at the place of observation, θ the inclination, ζ the azimuth of the ship's head, reckoning from (magnetic) north to west, and let ϕ', θ', ζ' represent the values of the same quantities, shown by an instrument placed at a fixed position in the vessel, and affected by the attraction of the iron in the vessel.

"'The first three equations in the memorandum in Contribution No. VI. may be transformed into the following, viz.—

$$\phi \cos \theta \cos \zeta = \phi' \cos \theta' \{A' \cos \zeta' + B' \sin \zeta'\} + \phi' \sin \theta' C' + P'. \quad (1.)$$

$$\phi \cos \theta \sin \zeta = \phi' \cos \theta' \{D' \cos \zeta' + E' \sin \zeta'\} + \phi' \sin \theta' F' + Q'. \quad (2.)$$

$$\phi \sin \theta = \phi' \cos \theta' \{G' \cos \zeta' + H' \sin \zeta'\} + \phi' \sin \theta' K' + R'. \quad (3.)$$

"'The coefficients A′ B′ . . . R′ might, if required, be expressed in terms of the corresponding coefficients of Contribution No. VI. It is here however only important to observe that A′ B′ C′ D′ E′ F′ G′ H′ K′ depend only on the amount and distribution of the *soft* iron. P′ Q′ R′ depend partly on the amount and distribution of the soft iron, and partly on the amount and distribution of the permanently magnetic iron, and become zero when there is no permanently magnetic iron. If the soft iron is symmetrically distributed on each side of the fore and aft vertical section passing through the compass, B′ D′ F′ H′ are equal to zero.

"'The above equations are deduced, it must be remembered, on the hypothesis that the *soft* iron of the vessel receives its full charge of induced magnetism instantly on the vessel assuming a new position, and that the rest of the iron in the vessel is in a permanently magnetic state. On this hypothesis, and supposing that no iron is very near the compass, the equations are *accurate*, and the coefficients A′ B′, &c. are *constant*, and *independent of the latitudes*. The hypothesis is however evidently not strictly true. The magnetic state of the hard, if not of the soft iron of the vessel, changes with a change of position and with time. In consequence of this, different values of the coefficients are derived from observations made at different places, and at the same place at different times.

"'Careful observations, made in a variety of circumstances and localities, and particularly, (for a reason which will appear in a subsequent part of this Memorandum,) observations made near the line of no dip, when the affected dip is zero, may hereafter throw light on the nature of the change which takes place in the magnetic state of a vessel, and furnish the means of determining the change which the coefficients undergo. In the present Memorandum they are supposed to be constant.

"'From equations (1.) and (2.) the following may be deduced:

$$\left.\begin{array}{l}\sin(\zeta-\zeta')=\frac{\varphi'\cos\theta'}{\varphi\cos\theta}\left\{\frac{\mathrm{D}'-\mathrm{B}'}{2}-\frac{\mathrm{A}'-\mathrm{E}'}{2}\sin 2\zeta'+\frac{\mathrm{B}'+\mathrm{D}'}{2}\cos 2\zeta'\right\}\\ \qquad\qquad -\frac{\varphi'\sin\theta'\mathrm{C}'+\mathrm{P}'}{\varphi\cos\theta}\sin\zeta'+\frac{\varphi'\sin\theta'\mathrm{F}'+\mathrm{Q}'}{\varphi\cos\theta}\cos\zeta'\end{array}\right\} \quad . \quad . \quad (4.)$$

"'This equation is rigorously accurate, on the assumptions which have been made. If $\varphi'\cos\theta'$ and $\varphi'\sin\theta'$ were known in terms of φ, θ and ζ', and the coefficients determined by observation, this equation would furnish accurate corrections for observations of Declination. The expression is very much simplified if we may assume $\theta'=\theta$, and $\varphi'=\varphi$. This assumption may I believe in general be safely made, except in high magnetic latitudes. Making this assumption, we have the following *approximate* formula,

$$\left.\begin{array}{l}\sin(\zeta-\zeta')=\frac{\mathrm{D}'-\mathrm{B}'}{2}-\left\{\mathrm{C}'\tan\theta+\frac{\mathrm{P}'}{\varphi\cos\theta}\right\}\sin\zeta'+\left\{\mathrm{F}'\tan\theta+\frac{\mathrm{Q}'}{\varphi\cos\theta}\right\}\cos\zeta'\\ \qquad\qquad -\frac{\mathrm{A}'-\mathrm{E}'}{2}\sin 2\zeta'+\frac{\mathrm{B}'+\mathrm{D}'}{2}\cos 2\zeta'\end{array}\right\} \quad . \quad . \quad (5.)$$

"'This equation may conveniently be put under the form

$$\sin\delta=\mathrm{A}+\mathrm{B}\sin\zeta'+\mathrm{C}\cos\zeta'+\mathrm{D}\sin 2\zeta'+\mathrm{E}\cos 2\zeta' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6.)$$

$\delta=\zeta-\zeta'$ is the deviation of the compass; B corresponds to the coefficient $a \tan \theta$ of the former memorandum; D to the coefficient $1-b$. A, B, C, D, E are coefficients, which are to be determined by observations of deviation made with the ship's head on different azimuths. A, D and E, it will be seen, are independent of the dip, and, to the extent to which the hypothesis above mentioned is correct, will have the same values in different latitudes. B and C depend on the dip, and also on the proportion of the soft to the permanently magnetic iron. This ratio cannot be determined from observations made in one place. If P′, Q′, C′, F′ remain constant, they can severally be determined from values of B and C deduced in *two* different latitudes, and the values of B and C in any other latitude may be deduced from the equations

$$B=-\left\{C' \tan \theta+\frac{P'}{\varphi \cos \theta}\right\} \ldots (7.) \qquad C=F' \tan \theta+\frac{Q'}{\varphi \cos \theta} \quad \ldots \quad (8.)$$

the accurate values of B and C being

$$B=-\frac{\varphi' \sin \theta' C'+P'}{\varphi \cos \theta'}, \qquad C=\frac{\varphi' \sin \theta' F'+Q'}{\varphi \cos \theta}.$$

If the affected dip is zero, we have

$$R=-\frac{P'}{\phi}, \qquad C=\frac{Q'}{\phi}.$$

So that from observations on the line of no dip, or more accurately when the affected dip is zero, the effect of the permanent magnetism may be obtained.

" 'If we distinguish the points of the compass, reckoning from north to west, by the numbers from 1 to 32, north being 0 or 32, and north by west being 1; and if we designate by δ_0, δ_1, &c. the westerly deviation when the ship's head is north, or north by west, &c., so that δ_8 represents the deviation at W., δ_{16} at S., δ_{24} at E., it is evident from the equations that we have at once the following simple expressions for the values of the coefficients:—

$$A=\frac{1}{4}\left\{\sin \delta_0+\sin \delta_8+\sin \delta_{16}+\sin \delta_{24}\right\} \quad \ldots \ldots \quad (9.)$$

$$B=\frac{1}{2}\left\{\sin \delta_8-\sin \delta_{24}\right\} \quad \ldots \ldots \quad (10.)$$

$$C=\frac{1}{2}\left\{\sin \delta_0-\sin \delta_{16}\right\} \quad \ldots \ldots \quad (11.)$$

$$D=\frac{1}{4}\left\{\sin \delta_4-\sin \delta_{12}+\sin \delta_{20}-\sin \delta_{28}\right\} \quad \ldots \ldots \quad (12.)$$

$$E=\frac{1}{4}\left\{\sin \delta_0-\sin \delta_8+\sin \delta_{16}-\sin \delta_{24}\right\} \quad \ldots \ldots \quad (13.)$$

" 'More accurate values of the coefficients may be obtained by combining observations of deviation, made with the ship's head on the several points, in the following manner:—

" '1. Suppose the deviation to have been observed on all the thirty-two points. Let

$\zeta'_1, \zeta'_2 \ldots . \zeta'_{32}$ be the observed azimuths, which of course are 11° 15′, 22° 30′, &c. Then we have

$$\left.\begin{array}{l} \sin\delta_0 = \mathrm{A} \qquad\qquad\quad +\mathrm{C} \qquad\qquad\qquad\qquad\quad +\mathrm{E} \\ \sin\delta_1 = \mathrm{A}+\mathrm{B}\sin\zeta'_1+\mathrm{C}\cos\zeta'_1+\mathrm{D}\sin 2\zeta'_1+\mathrm{E}\cos 2\zeta'_1 \\ \sin\delta_2 = \mathrm{A}+\mathrm{B}\sin\zeta'_2+\mathrm{C}\cos\zeta'_2+\mathrm{D}\sin 2\zeta'_2+\mathrm{E}\cos 2\zeta'_2 \\ \qquad \&\mathrm{c}. \qquad\qquad \&\mathrm{c}. \\ \sin\delta_{31} = \mathrm{A}+\mathrm{B}\sin\zeta'_{31}+\mathrm{C}\cos\zeta'_{31}+\mathrm{D}\sin 2\zeta'_{31}+\mathrm{E}\cos 2\zeta'_{31} \end{array}\right\} \quad . \quad . \quad . \quad (14.)$$

Combining these equations by the method of least squares, we obtain by virtue of a well-known property of circular functions,

$$\left.\begin{array}{l} \mathrm{A}=\frac{1}{32}\Sigma\sin\delta \\ \mathrm{B}=\frac{1}{16}\Sigma\sin\delta\sin\zeta' \\ \mathrm{C}=\frac{1}{16}\Sigma\sin\delta\cos\zeta' \\ \mathrm{D}=\frac{1}{16}\Sigma\sin\delta\sin 2\zeta' \\ \mathrm{E}=\frac{1}{16}\Sigma\sin\delta\cos 2\zeta' \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15.)$$

where $\Sigma\sin\delta = \sin\delta_0 + \sin\delta_1 \ldots\ldots + \sin\delta_{31}$,

$\Sigma\sin\delta\sin\zeta' = \sin\delta_0\sin\zeta'_0 + \sin\delta_1\sin\zeta'_1 + \&\mathrm{c}. + \sin\delta_{31}\sin\zeta'_{31}$

&c. &c. &c.

"'If we represent $\sin\delta_0$, $\sin\delta_1$, &c. by s_0, s_1, &c., and remember that all the values of $\sin\zeta'$, $\cos\zeta'$, $\sin 2\zeta'$, $\cos 2\zeta'$ which occur in these formulæ can be represented by the quantities s_1, s_2, s_3, s_4, s_5, s_6, s_7, we shall find

$$\mathrm{A}=\frac{1}{32}\{s_0+s_1+s_2 \quad . \quad . \quad . \quad . \quad +s_{31}\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16.)$$

$$\begin{array}{l} \mathrm{B}=\cdot 0122\,(\log=\bar{2}\cdot 08611)\{s_1-s_{31}+s_{15}-s_{17}\}, \\ \quad +\cdot 0239\,(\log=\bar{2}\cdot 37872)\{s_2-s_{30}+s_{14}-s_{18}\}, \\ \quad +\cdot 0347\,(\log=\bar{2}\cdot 54062)\{s_3-s_{29}+s_{13}-s_{19}\}, \\ \quad +\cdot 0442\,(\log=\bar{2}\cdot 64536)\{s_4-s_{28}+s_{12}-s_{20}\}, \\ \quad +\cdot 0520\,(\log=\bar{2}\cdot 71572)\{s_5-s_{27}+s_{11}-s_{21}\}, \\ \quad +\cdot 0577\,(\log=\bar{2}\cdot 76149)\{s_6-s_{26}+s_{10}-s_{22}\}, \\ \quad +\cdot 0613\,(\log=\bar{2}\cdot 78745)\{s_7-s_{25}+s_9-s_{23}\}, \\ \qquad\qquad +\frac{1}{16}\{s_8-s_{24}\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17.) \end{array}$$

$$\mathrm{C}=\frac{1}{16}\{s_0-s_{16}\},$$
$$+\cdot0613\ (\log=\bar{2}\cdot78745)\{s_1+s_{31}-s_{15}-s_{17}\},$$
$$+\cdot0577\ (\log=\bar{2}\cdot76149)\{s_2+s_{30}-s_{14}-s_{18}\},$$
$$+\cdot0520\ (\log=\bar{2}\cdot71572)\{s_3+s_{29}-s_{13}-s_{19}\},$$
$$+\cdot0442\ (\log=\bar{2}\cdot64536)\{s_4+s_{28}-s_{12}-s_{20}\},$$
$$+\cdot0347\ (\log=\bar{2}\cdot54062)\{s_5+s_{27}-s_{11}-s_{21}\},$$
$$+\cdot0239\ (\log=\bar{2}\cdot37872)\{s_6+s_{26}-s_{10}-s_{22}\},$$
$$+\cdot0122\ (\log=\bar{2}\cdot08611)\{s_7+s_{25}-s_9-s_{23}\}. \quad \ldots \quad (18.)$$

$$\mathrm{D}=\cdot0577\ (\log=\bar{2}\cdot76149)\{s_1-s_{31}-s_{15}+s_{17}+s_7-s_{25}-s_9+s_{23}\},$$
$$+\cdot0442\ (\log=\bar{2}\cdot64536)\{s_2-s_{30}-s_{14}+s_{18}+s_6-s_{26}-s_{10}+s_{22}\},$$
$$+\cdot0229\ (\log=\bar{2}\cdot37872)\{s_3-s_{29}-s_{13}+s_{19}+s_5-s_{27}-s_{11}+s_{21}\},$$
$$+\frac{1}{16}\{s_4-s_{28}-s_{12}+s_{20}\}. \quad \ldots \quad (19.)$$

$$\mathrm{E}=\frac{1}{16}\{s_0+s_{16}-s_8-s_{24}\},$$
$$+\cdot0239\ (\log=\bar{2}\cdot37872)\{s_1+s_{31}+s_{15}+s_{17}-s_7-s_{25}-s_9-s_{23}\},$$
$$+\cdot0442\ (\log=\bar{2}\cdot64536)\{s_2+s_{30}+s_{14}+s_{18}-s_6-s_{26}-s_{10}-s_{22}\},$$
$$+\cdot0577\ (\log=\bar{2}\cdot76149)\{s_3+s_{29}+s_{13}+s_{19}-s_5-s_{27}-s_{11}-s_{21}. \quad \ldots \quad (20.)$$

"'2. Using the deviations observed on the sixteen principal points only, we have

$$\mathrm{A}=\frac{1}{16}\{s_0+s_2+s_4 \quad \ldots \quad +s_{30}\}. \quad \ldots \quad (21.)$$

$$\mathrm{B}=\cdot0478\ (\log=\bar{2}\cdot67975)\{s_2-s_{30}+s_{14}-s_{18}\},$$
$$+\cdot0884\ (\log=\bar{2}\cdot94639)\{s_4-s_{28}+s_{12}-s_{20}\},$$
$$+\cdot1155\ (\log=\bar{1}\cdot06252)\{s_6-s_{26}+s_{10}-s_{22}\},$$
$$+\frac{1}{8}\{s_8-s_{24}\}. \quad \ldots \quad (22.)$$

$$\mathrm{C}=\frac{1}{8}(s_0-s_{16}),$$
$$+\cdot1155\ (\log=\bar{1}\cdot06252)\{s_2+s_{30}-s_{14}-s_{18}\},$$
$$+\cdot0884\ (\log=\bar{2}\cdot94639)\{s_4+s_{28}-s_{12}-s_{20}\},$$
$$+\cdot0478\ (\log=\bar{2}\cdot67975)\{s_6+s_{26}-s_{10}-s_{22}\}. \quad \ldots \quad (23.)$$

$$\mathrm{D}=\cdot0884\ (\log=\bar{2}\cdot94639)\{s_2-s_{30}-s_{14}+s_{18}+s_6-s_{26}-s_{10}+s_{22}\},$$
$$+\frac{1}{8}\{s_4-s_{28}-s_{12}+s_{20}\}. \quad \ldots \quad (24.)$$

$$\mathrm{E}=\frac{1}{8}\{s_0+s_{16}-s_8-s_{24}\},$$
$$+\cdot0884\ (\log=\bar{2}\cdot94639)\{s_2+s_{30}+s_{14}+s_{18}-s_6-s_{10}-s_{22}-s_{26}\}. \quad \ldots \quad (25.)$$

" '3. Using the deviations observed on the eight principal points only, we have

$$A=\frac{1}{8}\{s_0+s_4+s_8 \quad . \quad . \quad . \quad . \quad +s_{28}\}. \qquad (26.)$$

$$B=\cdot1768\,(\log=\bar{1}\cdot24742)\{s_4-s_{28}+s_{12}-s_{20}\},$$
$$+\frac{1}{4}\{s_8-s_{24}\}. \qquad (27.)$$

$$C=\frac{1}{4}\{s_0-s_{16}\},$$
$$+\cdot1768\,(\log=\bar{1}\cdot24742)\{s_4+s_{28}-s_{12}-s_{20}\}. \qquad (28.)$$

$$D=\frac{1}{4}\{s_4-s_{28}-s_{12}+s_{20}\}. \qquad (29.)$$

$$E=\frac{1}{4}\{s_0+s_{16}-s_8-s_{24}\}. \qquad (30.)$$

" ' Having found A, B, C, D, E by any of the above methods, a table of the deviations on all the points may then be computed. The computation will be facilitated by using the following Table :—

" ' Let B_1, B_2 . . . . B_7, C_1, C_2 . . . . C_7 represent the values of B and C multiplied by sin 11° 15′, sin 22° 30′, and let D_2, D_4, D_6, E_2, E_4, E_6 represent the values of D and E multiplied by sin 22° 30′, sin 45°, and sin 67′ 30°, we have then

$$\sin\delta_0=A+C+E$$
$$\sin\delta_{16}=A-C+E$$

$$\sin\delta_1=A+B_1+C_7+D_2+E_6$$
$$\sin\delta_{31}=A-B_1+C_7-D_2+E_6$$
$$\sin\delta_{15}=A+B_1-C_7-D_2+E_6$$
$$\sin\delta_{17}=A-B_1-C_7+D_2+E_6$$

$$\sin\delta_2=A+B_2+C_6+D_4+E_4$$
$$\sin\delta_{30}=A-B_2+C_6-D_4+E_4$$
$$\sin\delta_{14}=A+B_2-C_6-D_4+E_4$$
$$\sin\delta_{18}=A-B_2-C_6+D_4+E_4$$

$$\sin\delta_3=A+B_3+C_5+D_6+E_2$$
$$\sin\delta_{29}=A-B_3+C_5-D_6+E_2$$
$$\sin\delta_{13}=A+B_3-C_5-D_6+E_2$$
$$\sin\delta_{19}=A-B_3-C_5+D_6+E_2$$

$$\sin\delta_4=A+B_4+C_4+D$$
$$\sin\delta_{28}=A-B_4+C_4-D$$
$$\sin\delta_{12}=A+B_4-C_4-D$$
$$\sin\delta_{20}=A-B_4-C_4+D$$

$$\begin{aligned} \sin\delta_5 &= A+B_5+C_3+D_6-E_2 \\ \sin\delta_{27} &= A-B_5+C_3-D_6-E_2 \\ \sin\delta_{11} &= A+B_5-C_3-D_6-E_2 \\ \sin\delta_{21} &= A-B_5-C_3+D_6-E_2 \end{aligned}$$

$$\begin{aligned} \sin\delta_6 &= A+B_6+C_2+D_4-E_4 \\ \sin\delta_{26} &= A-B_6+C_2-D_4-E_4 \\ \sin\delta_{10} &= A+B_6-C_2-D_4-E_4 \\ \sin\delta_{22} &= A-B_6-C_2+D_4-E_4 \end{aligned}$$

$$\begin{aligned} \sin\delta_7 &= A+B_7+C_1+D_2-E_6 \\ \sin\delta_{25} &= A-B_7+C_1-D_2-E_6 \\ \sin\delta_9 &= A+B_7-C_1-D_2-E_6 \\ \sin\delta_{23} &= A-B_7-C_1+D_2-E_6 \end{aligned}$$

$$\begin{aligned} \sin\delta_8 &= A+B-E \\ \sin\delta_{24} &= A-B-E. \end{aligned}$$

“‘If the deviations are under 7° or 8°, the angles of deviation may be used in the formulæ instead of the sines of the angles without producing a sensible error in the result.

“‘It may be observed that $\varphi' \cos\theta'$ and $\varphi' \sin\theta'$ would be themselves properly expressed in a series containing sines and cosines of ζ' and $2\zeta'$, and this would introduce into the expression for $\sin\delta$ terms of the form

$$F\sin 3\zeta' + G\cos 3\zeta' + H\sin 4\zeta' + K\cos 4\zeta'.$$

“‘The omission of these terms from the formula we have used does not affect the values we have found for A, B, C, D, E; and the values of the additional coefficients may be determined from the following expressions, in which we make use of the observations on the sixteen principal points only:—

$$\begin{aligned} F = {} & \cdot1155\,(\log=\bar{1}\cdot06252)\{s_2-s_{30}+s_{14}-s_{18}\}, \\ & +\cdot0884\,(\log=\bar{2}\cdot94639)\{s_4-s_{28}+s_{12}-s_{20}\}, \\ & -\cdot0478\,(\log=\bar{2}\cdot67975)\{s_6-s_{26}+s_{10}-s_{22}\}, \\ & -\frac{1}{8}(s_8-s_{24}). \qquad (31.) \end{aligned}$$

$$\begin{aligned} G = {} & \frac{1}{8}(s_0-s_{16}) \\ & +\cdot0478\,(\log=\bar{2}\cdot67975)\{s_2+s_{30}-s_{14}-s_{18}\}, \\ & -\cdot0884\,(\log=\bar{2}\cdot94639)\{s_4+s_{28}-s_{12}-s_{20}\}, \\ & -\cdot1155\,(\log=\bar{1}\cdot06252)\{s_6+s_{26}-s_{10}-s_{22}\}. \qquad (32.) \end{aligned}$$

$$H=\frac{1}{16}\{s_2-s_{30}-s_{14}+s_{18}-s_6+s_{26}+s_{10}-s_{22}\}. \qquad (33.)$$

$$K=\frac{1}{16}\{s_0+s_{16}+s_8+s_{24}-s_4-s_{28}-s_{12}-s_{20}\}. \qquad (34.)$$

"'If the deviations are so small that the angles may be used instead of their sines, then the differences between the observed deviations and the deviations calculated with the first five terms may be used instead of s_2, s_4, &c. in finding F and G or H and K. There is however no advantage gained thereby, as the quantities within the brackets in F and G have already been found in calculating B and C.

"'As an example of the use of these formulæ, we may take the deviations observed on board Her Majesty's ship Erebus at Gillingham, in Sept. 1839[*].

"'From the deviations observed on the sixteen principal points, I find

$$\delta = 17' + 235'{\cdot}\sin\zeta' - 13'\cos\zeta' + 21'{\cdot}\sin 2\zeta' - 1'{\cdot}23\cos 2\zeta'.$$

"'From the deviations on the eight principal points, I find

$$\delta = 16' + 233'{\cdot}5\sin\zeta' - 14'{\cdot}\cos\zeta' + 21\sin 2\zeta' - 0'{\cdot}75\cos 2\zeta'.$$

"'Applying the correction derived from the first formula, the residuary differences on the sixteen principal points, beginning with north, are respectively—

$$-3', 0, +6', +14', -6', -18', +12', +7', +1', -11', -12', -9', +5', +7', +6', 0.$$

"'These differences evidently nearly follow the law of $\sin 3\zeta'$; they give

$$F = 5'{\cdot}5;\quad G = -7'.$$

"'After applying the correction $5'{\cdot}5\sin 3\zeta' - 7'\cos 3\zeta'$, the residuary difference is

$$+4'\ -2', -3', +9', 0', -9', +13', -1', -6', -9', -3', -4', -1', -2', +5', +8'.$$

"'The differences, it will be seen, are smaller, and do not distinctly follow any regular law. If we calculate H and K we shall find

$$H = 2';\quad K = 1'.$$

But these corrections are so much within the errors of observation, that there could be no advantage in using them.

"'The expression for $\sin\delta$ may be put under the following form, viz.—

$$\sin\delta = A + \sqrt{B^2+C^2}\,\sin(\zeta'+\alpha) + D\sin 2\zeta' + E\cos 2\zeta', \quad . \quad . \quad . \quad . \qquad (35.)$$

in which α is the angle whose tangent is $\frac{C}{B}$, and is nearly the easterly azimuth of the line of no deviation.

"'It seems probable that in ordinary cases A, α, D and E will not change materially with a change of latitude, while $\sqrt{B^2+C^2}$ will vary nearly as the tangent of the dip. The last-mentioned term is also the most important, from its magnitude and its dependence on the changes which the permanent magnetism undergoes. It may therefore be useful to have the means of obtaining this quantity separately. This may be done from observations of the horizontal force, made in the position of the standard compass, with the ship's head on any two opposite (affected) courses, from the formula

$$\sqrt{B^2+C^2} = \frac{\sqrt{H_1^2 + H_2^2 + 2H_1H_2\cos(\text{diff. of true azimuth})}}{H_1+H_2}, \quad . \quad . \quad . \qquad (36.)$$

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[*] Contributions, No. V., p. 150.

in which H_1 H_2 represent the observed horizontal force in the two positions of the ship's head.

" 'If the difference of the true azimuths of the ship's head is 180°, the expression becomes

$$\sqrt{B^2+C^2}=\pm\frac{H_1-H_2}{H_1+H_2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (37.)$$

which is the same expression as that for the value of $\alpha \tan \theta$ in the Memorandum in No. V. of these Contributions.

" 'The value of the horizontal force may be determined by vibrating a horizontal needle, or by deflecting the compass needle in the manner described by Lieut. Clerk in page 347. The difference of azimuths may be determined by the bearings of a distant object, or astronomically.

" 'This method seems to be adapted to the case of a ship lying at moorings in a tideway. The observations may be made before and after the change of tide, and the rudder adjusted so that the difference of the compass bearings of the ship's head may be exactly 180°.

" 'This formula is more accurate the more nearly the dip approaches to 90°; and the method seems therefore particularly applicable in high magnetic latitudes.

" 'If the true magnetic azimuth of the ship's head on the two positions is determined, the values of B and C may be obtained by the formula

$$B=-\frac{H_2\cos\zeta_1+H_1\cos\zeta_2}{H_1+H_2},$$

$$C=\frac{H_2\sin\zeta_1+H_1\sin\zeta_2}{H_1+H_2}.$$

" 'A. S.'

" '*Lincoln's Inn, March* 3, 1846.'

" The constants for correcting the declination observations were (in consequence of this Memorandum) calculated by the equations 21, 22, 23, 24 and 25, taking the mean of the two series at the Cape of Good Hope.

" The following are the deduced values of the constants :—

Station.	θ.	φ.	A.	B.	C.	D.	E.
Cape of Good Hope	−53° 44′	1·013	+·00600	−·01412	+·00742	+·00911	−·00333
Mauritius	−53 56	1·158	+·00479	−·01550	+·00514	+·00448	+·00335
King George's Sound...........	−65 04	1·703	+·01453	−·03295	+·00658	−·00156	+·00082
Means...............	−57 35	1·291	+·00844	−·02086	+·00638	+·00401	+·00028

" From the three values of B, and C, values of C′ and P′, F′ and Q′ were obtained by the equations

$$B=-\left(C'\tan\theta+\frac{P}{\phi\cos\theta}\right);\ \text{and}\ C=F'\tan\theta+\frac{Q}{\phi\cos\theta};$$

for we have

Cape . . $-\cdot01412 = C' \times 1\cdot363 + P' \times 1\cdot669$; also $+\cdot00742 = -1\cdot363F' - 1\cdot669Q'$

Mauritius . $-\cdot01550 = C' \times 1\cdot373 + P' \times 1\cdot467$; also $+\cdot00514 = -1\cdot373F' - 1\cdot467Q'$

King George's Sound . $-\cdot03295 = C' \times 2\cdot151 + P' \times 1\cdot393$; also $+\cdot00658 = -2\cdot151F' - 1\cdot393Q'$.

Hence by elimination we obtain

$$C' = -\cdot0209;\quad F' = -\cdot0006;$$
$$P' = +\cdot0088;\quad Q' = -\cdot0034.$$

"From the values of C', P', F' and Q', a table of the values of B and C in different dips and intensities was formed, and from them with the mean values of A, D and E, a table for correcting the observations of Declination was calculated by equ. 35. The corrections thus obtained appear to give very closely the true corrections, at all events much within the limits of observation errors. The following is a comparison between the observed and calculated deviations at King George's Sound, θ being $= -65° 04'$, and $\varphi = 1\cdot70$.

Ship's head.	δ by calculation.	δ by observation.	Difference.	Ship's head.	δ by calculation.	δ by observation.	Difference.
N.	+0° 52′	+0° 15′	−0° 37′	S.	+0° 03′	+0° 50′	+0° 47′
N.N.W.	+0 17	0 00	−0 17	S.S.E.	+0 47	+0 55	+0 08
N.W.	−0 21	+0 20	+0 41	S.E.	+1 25	+2 20	+0 55
W.N.W.	−0 58	−1 40	−0 42	E.S.E.	+2 02	+3 10	+1 08
W.	−1 25	−1 40	−0 15	E.	+2 25	+2 40	+0 15
W.S.W.	−1 16	−1 50	−0 34	E.N.E.	+2 17	+3 10	+0 53
S.W.	−0 54	−1 00	−0 06	N.E.	+1 52	+3 30	+1 38
S.S.W.	−0 24	−0 24	+0 09	N.N.E.	+1 22	+2 35	+1 13

+ Sign denotes a deviation towards the west.

"It appears from this comparison, that the calculated corrections are smaller in amount than the observed. As the ship had just returned from a high magnetic latitude, it is probable that the observed corrections belonged to a greater dip than the one at the station, and therefore that the corrections would be more nearly represented by taking them out from the Table for a larger Inclination and Intensity. The great differences on the E.S.E., N.E. and N.N.E. points are caused most probably by errors of observation.

"The correctness of equation (6.) will be more easily perceived by the accordance of observations made at sea, in a high dip, making due allowance for the difficulty of observing in bad weather.

"2. *Calculation of Corrections for the Inclination Observations.*

"To obtain these corrections four constants are necessary, viz. *a*, *b*, *c*, *d*; *a* and *b* are obtained from the deviations of a compass (placed on the same spot as the dipping-needle) on the sixteen principal points. The following are the observations at King George's Sound, the Mauritius, and the Cape of Good Hope.

Ship's head.	King George's Sound.	Mauritius.	Cape of Good Hope.	Ship's head.	King George's Sound.	Mauritius.	Cape of Good Hope.
N.	−0° 45′	−0° 05′	−0° 25′	S.	Not observed.	+1° 25′	−0° 50′
N.N.W.	−1 15	−1 25	Not observed.	S.S.E.	+2 40	+1 15	Not observed.
N.W.	−2 05	−1 45	−0 05	S.E.	+3 25	+1 10	+1 55
W.N.W.	−3 20	−2 25	−0 35	E.S.E.	+3 25	+1 50	+2 35
W.	−3 35	−3 05	−0 50	E.	+3 25	+2 15	+2 40
W.S.W.	−3 45	−3 05	−1 15	E.N.E.	+2 35	+1 05	+1 10
S.W.	−1 55	−1 35	−1 45	N.E.	+2 45	+0 35	+0 45
S.S.W.	*3 00	−1 05	−0 35	N.N.E.	+2 20	+0 25	+0 05

"Allowing for the errors of observation, it appears from these observations that the iron is symmetrically distributed in reference to the compass placed on the same spot where the observations of inclination and intensity were made, and therefore that we may use the equations in Contributions V. and VI.

"From these equations the values of a and b are found,—

At King George's Sound . . . . $a=\cdot 0296$; $b=\cdot 9867$;
Mauritius . . . . $a=\cdot 0272$; $b=\cdot 9910$;
Cape of Good Hope . . . . . $a=\cdot 0192$; $b=\cdot 9766$.

"The values of a and b can be found independently of the compass, from the observations of dip and intensity themselves, A' being supposed $=1$, by means of the formulæ

$$a\sin\theta=\frac{\phi'}{\phi}\cos\theta'\cos\zeta'-\cos\theta\,.\cos\zeta, \quad \text{. . . . . (1.)}$$

and

$$b\cos\theta=\frac{\phi'}{\phi}\cos\theta'\sin\zeta'\cos\zeta. \quad \text{. . . . . (2.)}$$

"Values of ϕ' and θ' were obtained from observations on the sixteen principal points of the compass made at King George's Sound, Mauritius, and the Cape of Good Hope. They are as follows:—

Values of θ'.

Ship's head.	Observed Inclination.			Ship's head.	Observed Inclination.		
	King George's Sound.	Mauritius.	Cape of Good Hope.		King George's Sound.	Mauritius.	Cape of Good Hope.
N.	−66° 15′	−54° 38′	−54° 01′	S.	−64° 52′	−53° 46′	−53° 28′
N.N.W.	−66 33	−54 44	−54 35	S.S.E.	−65 00	−53 41	−53 50
N.W.	−66 19	−54 47	−54 56	S.E.	−65 29	−54 20	−53 51
W.N.W.	−66 07	−55 02	−54 47	E.S.E.	−65 52	−54 25	−54 24
W.	−65 44	−55 21	−54 46	E.	−66 23	−54 50	−54 46
W.S.W.	−65 42	−54 39	−54 31	E.N.E.	−66 07	−54 55	−54 53
S.W.	−65 31	−54 29	−53 45	N.E.	−66 17	−54 47	−54 37
S.S.W.	−64 48	−54 07	−53 09	N.N.E.	−66 31	−54 27	−54 25

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* This observation is not taken into account, being obviously erroneous.

Values of ϕ'.

Ship's head.	Observed Intensity.			Ship's head.	Observed Intensity.		
	King George's Sound.	Mauritius.	Cape of Good Hope.		King George's Sound.	Mauritius.	Cape of Good Hope.
N.	1·737	1·150	1·024	S.	1·799	1·206	1·066
N.N.W.	1·736	1·152	1·020	S.S.E.	1·797	1·204	1·055
N.W.	1·734	1·151	1·025	S.E.	1·790	1·182	1·045
W.N.W.	1·752	1·158	1·025	E.S.E.	1·773	1·189	1·032
W.	1·758	1·166	1·028	E.	1·753	1·169	1·029
W.S.W.	1·775	1·198	1·036	E.N.E.	1·757	1·166	1·024
S.W.	1·790	1·191	1·049	N.E.	1·736	1·159	1·023
S.S.W.	1·805	1·200	1·061	N.N.E.	1·735	1·155	1·023

"The observed values of θ and ϕ are approximately—

King George's Sound . . $\theta = -65^\circ\ 11'$; $\phi = 1·733$
Mauritius . . . . $\theta = -54\ 14$; $\phi = 1·158$
Cape of Good Hope . . . $\theta = -53\ 37$; $\phi = 1·027$.

"Substituting these values in equations (1.) and (2.), we have

King George's Sound . . $a = ·0242$; $b = ·9905$;
Mauritius . . . . $a = ·0234$; $b = 1·0105$;
Cape of Good Hope . . . $a = ·0186$; $b = ·9916$.

"Including these values with those obtained from the compass observations, we get the mean values for a and b,

$$a = ·0237;\quad b = ·9912.$$

"The constants c and d are calculated from the formula

$$c \cos \zeta + d \tan \theta = b \sin \zeta \operatorname{cosec} \zeta' \tan \theta'$$

for the observations between N.N.W. and S.S.W., and N.N.E. and S.S.E.; and for the other points, viz. N. and S., by the formula

$$c \cos \zeta + d \tan \theta = (\cos \zeta + a \tan \theta) \sec \zeta' \tan \theta'.$$

"The values of ζ and θ' were given by the observations at the several stations. The values of c and d are as follows:—

King George's Sound . . $c = ·010$; $d = 1·054$;
Mauritius . . . . $c = ·014$; $d = 1·011$;
Cape of Good Hope . . . $c = ·003$; $d = 1·033$.

The values of c and d were also obtained from the observations of dip and intensity, independently of a and b, by the formula

$$c \cos \theta \cos \zeta - d \sin \theta = \frac{\phi'}{\phi} \sin \theta',$$

A being supposed equal to unity; which gives the following values:—

King George's Sound . . $c = {\cdot}028$; $d = 1{\cdot}023$;
Mauritius . . . . $c = {\cdot}024$; $d = 1{\cdot}017$;
Cape of Good Hope . . . $c = {\cdot}021$; $d = 1{\cdot}020$.

"The mean of these six values makes

$$c = {\cdot}017;\quad d = 1{\cdot}026.$$

"From these values of a, b, c and d, a table of corrections was found by means of equations (12.) and (13.) (Contribution V.), employing calculated values of ζ.

"In order to test the accuracy of the table, we may compare observed and calculated values of the dip at King George's Sound. It will be seen that on the northerly points the correction is rather too large, on the easterly and westerly too small, and nearly correct on the S., S.S.W. and S.S.E. points. The differences however are within the limits of observation errors.

Ship's head.	Observed Inclination.	Tabular correction.	Corrected Inclination.	
	° ′	° ′	° ′	° ′
N.	−66 15	+1 23	−64 52	−65 08
N.N.W. and N.N.E.	−66 32	+1 23	−65 09	
N.W. and N.E.	−66 18	+1 31	−64 47	
W.N.W. and E.N.E.	−66 07	+1 09	−64 58	
W. and E.	−66 03	+0 46	−65 17	
W.S.W. and E.S.E.	−65 47	+0 23	−65 24	
S.W. and S.E.	−65 30	+0 02	−65 28	
S.S.W. and S.S.E.	−64 54	−0 16	−65 10	
S.	−64 52	−0 18	−65 10	

The mean inclination observed on shore with the same needle being −65° 11′.

"3. *Calculation of Corrections for Intensity Observations.*

"The constant A is calculated from the above observations by means of the formula

$$\frac{\phi'}{A'\phi}\sin\theta' = c\cos\theta\cos\zeta + d\sin\theta.$$

"The values of θ', ϕ' and ζ, are all given by the observations on the sixteen points of the compass; those of ϕ and θ by the observations on shore. The following are the resulting values for A′, viz.—

King George's Sound . . . $A' = 0{\cdot}998$
Mauritius . . . . $A' = 0{\cdot}992$
Cape of Good Hope . . . . $A' = 0{\cdot}992$
Mean . . $A' = 0{\cdot}994$

"This value being so near unity, A is assumed $= 1{\cdot}0$, with which and the values of c and d already determined, a table of corrections was formed by means of the equation

$$\frac{\phi'}{\phi} = A'c\left(\frac{d}{c}\tan\theta + \cos\zeta\right)\cos\theta\,\mathrm{cosec}\,\theta'\text{[*]},$$

θ' and ζ being obtained from the tables for correcting the dips and declinations.

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[*] Philosophical Transactions, 1843, Part II. p. 162.

"II. *Determination of Index Corrections.*

"1. *Declination Observations.*

"The compass used was one of the Admiralty compasses (B. 20). It was supplied with two cards, one considerably heavier than the other to be used in bad weather; but as it was found that in all weathers the heavy card was the steadiest and gave the best results, it was accordingly generally used. The index corrections of both cards were determined at the Magnetic Observatory, Cape of Good Hope. The following are the means of several observations with each card; the mean monthly declination by the observatory declinometer being +29° 07′.

Card A (the light card) gave .	+28° 20′;	correction +47′.
Card J (the heavy card) gave .	+28 15;	correction +52.

"These corrections have been applied to all the observations, according to the card employed.

"2. *Inclination Observations.*

"Two of Mr. Fox's instruments were kept in constant use, one observed in the forenoon and the other in the afternoon. In order to distinguish them, we may call the one observed in the morning No. 1, the other was marked C. 9. In No. 1, needle 1 was mounted and used throughout, the spare needle 2 being used as a deflector. The index correction for 1 was determined at the Magnetic Observatory at the Cape, both before and after the Expedition, by comparing the inclination with the face of the instrument west (that being the way the observations were taken on board) with the mean monthly inclination shown by the observatory needles. The following are the observations with the deflectors at 40° from the apparent dip:—

November 10, 1844, needle 1, face west	−53° 39′;	correction + 8′
November 10, 1844, needle 1, face east	−53 59;	correction +28
November 21, 1844, needle 1, face west	−53 38;	correction + 7
November 21, 1844, needle 1, face east	−53 58;	correction +27

The mean monthly inclination being −53° 31′.

"After the 13th of January it was found more convenient to adjust the deflectors at the apparent dip, and make the same observations serve both for dip and intensity. The index corrections to be applied in this case are given by the following observations:—

Date.	Observed Inclination.—Face West.					True Inclination.	Index correction.
	Direct.	Def. N.	Def. S.	Def. N and S.	Mean.		
1844.							
December 1 ...	−53° 52′	−53° 21′	−53° 44′	−53° 39′	−53° 39′	−53° 31′	+07′
December 5 ...	−53 49	−53 20	−53 43	−53 38	−53 38		
1845.							
June 30	−54 12	−53 13	−53 46	−53 51	−53 45	−53 25	+19
July 2	−54 08	−53 15	−53 46	−53 43	−53 43		
Mean......	−54 01	−53 17	−53 45	−53 43	−53 41	−53 28	+13

"Magnets N and S are the small magnets belonging to the apparatus used conjointly; deflector N and deflector S are the respective poles of the spare needle. +13′ has been applied in all cases except when only magnets N and S have been used, in which case +24′ has been used, that being the mean correction for direct and magnets N and S.

"For the index corrections for needle A of C. 9, we have only an observation in Simon's Bay, Cape of Good Hope, before starting. Needle A was used from the Cape to King George's Sound, and was observed on shore at King George's Sound on the 7th of April. On the 10th it was found, from the discordance of the observations, that its axle had been damaged since the observations on the 7th, it was therefore taken out and needle B mounted in its place. The instrument had a third needle C which was used as a deflector. The small magnets were also used, both conjointly and separately. The observation in Simon's Bay gives,—

For C. 9, needle A . . . . −53° 24′ } Index correction −26′.
Corrected inclination, needle 1 . . . −53° 50′ }

This correction has been applied to all observations made with needle A of C. 9. For the correction of needle B, we have a comparison at the Cape of Good Hope after the return of the Expedition, and also at Woolwich, in January 1846. All observations with this instrument were taken with the face east.

"The following are the observations at the Cape:—

Date.	Observed Inclination.—Face East.							True Inclination.	Index correction.
	Direct.	Def. N.	Def. S.	Mag. N and S.	Mag. N.	Mag. S.	Mean.		
1845. June 30.	−53° 56′	−54° 15′	−52° 47′	−54° 06′	−53° 29′	−53° 23′	−53° 40′	−53° 25′	+15′
July 2.	−53 41	−54 11	−52 55	−54 15	−53 49	−53 41	−53 45	−53 25	+20
Mean...	−53 48	−54 13	−52 51	−54 10	−53 39	−53 32	−53 43	−53 25	+18

"And at Woolwich:—

Date.	Observed Inclination.—Face East.							True Inclination.	Index correction.
	Direct.	Def. N.	Def. S.	Mag. N and S.	Mag. N.	Mag. S.	Mean.		
1846. Jan. 13.	+68° 58′	+68° 02′	+68° 37′	+68° 24′	+68° 32′	+68° 30′	+68° 31′	+68° 58′	+22′
15.	+68 56	+68 21	+68 52	+68 45	+68 35	+68 34	+68 41		
Mean...	+68 57	+68 12	+68 44	+68 35	+68 33	+68 32	+68 36	+68 58	+22

"The index correction obtained at the Cape has been used for all the observations taken with this needle.

"3. *Elements of Calculation of the Intensity Observations.*

"Fox No. 1.—For the observations with this instrument, the Cape of Good Hope has been taken as a base station, the intensity having been observed there both before and after the Expedition, so that any change in the magnetism of the deflectors or needles can be detected.

"The intensity at Woolwich being assumed =1·372, it is necessary to get the corresponding intensity at the Cape. This can be got independent of the dipping-needles, by means of the absolute horizontal intensity and inclination observed at each station.

"The value of the horizontal intensity at the Cape is given as follows by observations made at the observatory in February, March, April and May 1845 :—

"Observations of the Absolute Horizontal Intensity, at the Magnetic Observatory, Cape of Good Hope, 1845.

Bar. A. 21. Suspended . . . length 3·00 inch . . . $\left(1+\frac{\mathrm{H}}{\mathrm{F}}\right)=1{\cdot}00084$.

Bar. V. Deflecting . . . length 3·67 inch . . . $q = {\cdot}00008$ . . . $\log \pi^2 . k = 1{\cdot}57254$.

Date.	Angles of Deflection.		Corrected time of vibration.	Temperature during		Bifilar readings at 60 during		Results.		
	Dist. 1·2 ft.	Dist. 1·3 ft.		Deflection.	Vibration.	Deflection.	Vibration.	*m.*	X.	
1845.	° ′	° ′	s	°	°	Scale dir.	Scale dir.			
Feb. 10, 11, 12.	6 05·1	4 47·5	4·4970	71·4	71·7	185·9	185·8	0·4118	4·488	4·482
Mar. 10, 11, 12.	6 01·1	4 44·0	4·5310	71·4	71·9	186·0	185·8	0·4064	4·480	
Apr. 13, 14, 15.	5 57·5	4 41·2	4·5570	62·9	62·6	176·9	177·4	0·4019	4·478	
May 14, 15, 16.	5 55·5	4 39·2	4·5650	60·7	59·9	177·2	177·5	0·4001	4·482	

"The value of *k* is obtained by means of two cylindrical weights in the usual manner; the value employed is the mean of several determinations. Bifilar magnetometer $k={\cdot}000218$, $q={\cdot}000218$. Increase of reading denotes increase of force.

Whence $\mathrm{X}=4{\cdot}482$, θ being $=-53^\circ\ 25'{\cdot}5$.

"The corresponding values at Woolwich are

$\mathrm{X}=$*$3{\cdot}7284$, θ being $=+68^\circ\ 57'{\cdot}9$.

"From these values of X and θ, we obtain the relative value of the intensity at the Cape (that at Woolwich being 1·372), I=0·993.

"The relative intensity given by the needles of No. 1, from observations made at Woolwich and the Cape and given in the sequel, are as follows :—

$$\text{Needle 1.}\begin{cases}\text{Weight 1 gr. } \mathrm{I}=0{\cdot}996\\ \text{Weight 2 grs. } \mathrm{I}=1{\cdot}017\end{cases}1{\cdot}006. \quad \text{Needle 2.}\begin{cases}\text{Weight 1 gr. } \mathrm{I}=0{\cdot}994\\ \text{Weight 2 grs. } \mathrm{I}=1{\cdot}006\end{cases}1{\cdot}000.$$

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* Contributions, No. VII.; Philosophical Transactions, 1846, p. 246.

"The value of I at the Cape has therefore been assumed provisionally as unity; subject to future correction should any appear to be required.

"The spare needle 2 was always used as a deflector; the two small magnets were used conjointly only with this apparatus.

"Tables of equivalent weights were made at the Cape both before and after the Expedition, according to the method given in the instructions for the use of Mr. Fox's instrument. The following Table contains the mean of the two series.

Def. N.		Def. S.		Mag. N and S.		Def. N. (Continued.)		Def. S. (Continued.)		Mag. N. and S. (Continued.)	
v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.
°	gr.	°	gr.	°	grs.	°	gr.	°	gr.	°	grs.
21	1·816	22	1·950	41	3·608	31	1·843	32	1·935	51	2·786
22	1·835	23	1·964	42	3·522	32	1·828	33	1·918	52	2·717
23	1·850	24	1·972	43	3·438	33	1·814	34	1·903	53	2·654
24	1·861	25	1·977	44	3·350	34	1·801	35	1·891	54	2·595
25	1·867	26	1·983	45	3·262	35	1·788	36	1·868	55	2·535
26	1·868	27	1·980	46	3·179	36	1·770	37	1·852	56	2·480
27	1·867	28	1·977	47	3·093	37	1·756	38	1·833	57	2·428
28	1·866	29	1·968	48	3·013	38	1·744	39	1·812	58	2·377
29	1·861	30	1·960	49	2·933	39	1·726	40	1·793	59	2·330
30	1·858	31	1·946	50	2·853	40	1·707	41	1·775	60	2·278

"With these values of w', and the following values of v and w, the values of I' have been calculated by the formula

$$I' = I \frac{\sin v . w'}{\sin v' . w} \text{ when deflectors are used, and}$$

$$I' = I \frac{\sin v}{\sin v'} \text{ when weights are used.}$$

Values of v at the Cape of Good Hope.

Date.	Def. N. $w=1·721$.	Def. S. $w=1·782$.	Mag. N and S. $w=2·337$.	Weight 1 grain.	Weight 2 grains.	Weight 2½ grains.
1844.						
Dec. 1.	39° 06′	40° 38′	59° 23′	21° 30′	46° 54′	65° 22′
5.	39 01	40 37	59 22	21 34	46 33	65 20
1845.						
June 30.	39 31	40 39	58 16	21 38	46 32	65 30
July 2.	39 22	40 39	58 21	22 06	46 21	65 30
Mean...	39 15	40 38	58 51	21 42	46 35	65 25

"From this Table it is evident that, with the exception of magnets N and S, the needles preserved their magnetism throughout the voyage. Magnets N and S lost magnetism to the amount of ·033. The mean of the four observations have been taken; the early intensities by this method will therefore be rather too small, the latter ones rather too great.

"The formulæ for calculation are as follows:—

Def. N. . . . . $I' = \cdot 3677 \operatorname{cosec} v' \,.\, w'$.
Def. S. . . . . $I' = \cdot 3654 \operatorname{cosec} v' \,.\, w'$.
Mag. N and S . . . . . $I' = \cdot 3659 \operatorname{cosec} v' \,.\, w'$.
Weight 1 grain . . . . $I' = \cdot 3698 \operatorname{cosec} v' \,.\, w'$.
Weight 2 grains . . . . $I' = \cdot 7264 \operatorname{cosec} v' \,.\, w'$.
Weight $2\frac{1}{2}$ grains . . . $I' = \cdot 9094 \operatorname{cosec} v' \,.\, w'$.

"Fox C. 9.—The values of the intensity at the Cape by the observations before and after the Expedition, by Fox, No. 1, are:—

$$\left.\begin{array}{ll} \text{Before . . . . . .} & I = 0\cdot 999 \\ \text{After . . . .} & I = 1\cdot 001 \end{array}\right\} \text{diff. } \cdot 002.$$

"These values agreeing so closely, we may assume that the intensity at King George's Sound with this apparatus will be very near the truth, and that King George's Sound may therefore be taken as a base station for needle A of C. 9, which was not observed at the Cape before our departure. The intensities were observed with needle A mounted, from the Cape to King George's Sound, when the needle got unfortunately damaged, and it was necessary to replace it with needle B: one day's observations had however been made before the accident, and these observations serve for calculating the intensities taken on the voyage, assuming the intensity at King George's Sound to be that given by the other apparatus, viz. 1·688.

"The same deflectors and weights were used throughout; the spare needle C as a deflector, the two small magnets both conjointly and separately.

"Tables of equivalent weights for these deflectors, with needle A mounted, were obtained in the same way as in the case of the other apparatus. They are as follows:

Def. N.		Def. S.		Mag. N and S.		Mag. N.		Mag. S.	
v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.
°	grs.	°	grs.	°	grs.	°	grs.	°	grs.
50	2·175	50	2·206	70	2·625	50	1·578	50	1·975
49	2·200	49	2·247	69	2·675	49	2·028	49	2·025
48	2·225	48	2·288	68	2·725	48	2·078	48	2·075
47	2·263	47	2·323	67	2·775	47	2·130	47	2·125
46	2·300	46	2·357	66	2·825	46	2·182	46	2·175
45	2·338	45	2·388	65	2·875	45	2·235	45	2·240
44	2·375	44	2·419	64	2·925	44	2·288	44	2·304
43	2·413	43	2·460	63	2·982	43	2·341	43	2·368
42	2·450	42	2·500	62	3·038	42	2·394	42	2·433
41	2·488	41	2·538	61	3·094	41	2·447	41	2·498
40	2·525	40	2·575	60	3·150	40	2·500	40	2·563
39	2·565	39	2·615	59	3·222	39	2·570	39	2·623
38	2·605	38	2·655	58	3·294	38	2·640	38	2·683
37	2·645	37	2·695	57	3·365	37	2·710	37	2·743
36	2·685	36	2·735	56	3·436	36	2·780	36	2·803
35	2·725	35	2·775	55	3·507	35	2·850	35	2·863
34	2·755	34	2·806	54	3·595	34	2·900	34	2·937
33	2·785	33	2·837	53	3·683	33	2·950	33	3·011
32	2·815	32	2·869	52	3·770	32	3·000	32	3·085
31	2·845	31	2·901	51	3·857	31	3·050	31	3·158
30	2·875	30	2·932	50	3·944	30	3·100	30	3·232
29	2·900	29	2·954	49	4·047				
28	2·925	28	2·975	48	4·150				

"The angles of deflection observed at King George's Sound are as follows:—

Def. N. $w=2{\cdot}779$.	Def. S. $w=2{\cdot}821$.	Mag. N and S. $w=3{\cdot}909$.	Mag. N. $w=2{\cdot}875$.	Mag. S. 2·895.	Weight 1 grain.	Weight 1½ grain.	Weight 2 grains.	Weight 2½ grains.	Weight 3 grains.
33° 11′	33° 32′	50° 24′	34° 30′	34° 34′	10° 44′	17° 16′	22° 55′	28° 18′	35° 10′

"Employing the values of v and w (I being $=1{\cdot}688$), we get formulæ for calculating the intensities, viz.—

Def. N . . . . $I'=\cdot 3325 \operatorname{cosec} v' . w'$.
Def. S . . . . . $I'=\cdot 3306 \operatorname{cosec} v' . w'$.
Mag. N and S $I'=\cdot 3327 \operatorname{cosec} v' . w'$.
Mag. N . . . . $I'=\cdot 3326 \operatorname{cosec} v' . w'$.
Mag. S . . . . $I'=\cdot 3308 \operatorname{cosec} v' . w'$.

Weight 1 grain . . $I'=\cdot 3144 \operatorname{cosec} v'$.
Weight 1½ grain. . $I'=\cdot 5010 \operatorname{cosec} v'$.
Weight 2 grains . . $I'=\cdot 6573 \operatorname{cosec} v'$.
Weight 2½ grains . $I'=\cdot 8003 \operatorname{cosec} v'$.
Weight 3 grains . . $I'=\cdot 9722 \operatorname{cosec} v'$.

Comparing observations made at sea near the Cape with those given by the other needle, the deflectors of this apparatus do not appear to have lost magnetism.

"From King George's Sound to the Cape, needle B was mounted, the same deflectors and weights being used as with needle A. The Cape of Good Hope has been taken as the base station in this case, the intensity having been observed there on the return of the Expedition.

"The table of equivalent weights is given below.

Def. N.		Def. S.		Mag. N and S.		Mag. N.		Mag. S.	
v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.	v'.	w'.
29°	1·794	35°	2·104	50°	2·763	31°	1·891	36°	2·174
30	1·782	36	2·076	51	2·701	32	1·862	37	2·122
31	1·765	37	2·046	52	2·638	33	1·833	38	2·069
32	1·748	38	2·015	53	2·576	34	1·804	39	2·012
33	1·734	39	1·986	54	2·513	35	1·773	40	1·954
34	1·719	40	1·956	55	2·457	36	1·741	41	1·903
35	1·697	41	1·927	56	2·401	37	1·705	42	1·851
36	1·675	42	1·898	57	2·345	38	1·669	43	1·801
37	1·657	43	1·865	58	2·288	39	1·635	44	1·751
38	1·638	44	1·832	59	2·247	40	1·600	45	1·707
39	1·619	45	1·799	60	2·203	41	1·563	46	1·663
40	1·600	46	1·766	61	2·167	42	1·525	47	1·626
41	1·582	47	1·740	62	2·110	43	1·494	48	1·588
42	1·563	48	1·713	63	2·071	44	1·463		
43	1·541	49	1·684	64	2·032	45	1·443		
44	1·519	50	1·654	65	1·996				
45	1·491			66	1·960				
				67	1·927				

"The following are the angles of deflection on three separate days at the Magnetic Observatory, Cape of Good Hope:—

Def. N. $w=1{\cdot}500$.	Def. S. $w=1{\cdot}659$.	Mag. N and S. $w=1{\cdot}953$.	Mag. N. $w=1{\cdot}480$.	Mag. S. $w=1{\cdot}615$.	Weight 1 grain.	Weight 1½ grain.	Weight 2 grains.
44° 32′	49° 48′	66° 02′	43° 21′	47° 13′	28° 00′	44° 10′	69° 31′
45 00	49 59	66 20	43 45	47 23			
44 33	49 42	66 16	43 15	47 20	28 26	44 16	69 15
44 42	49 50	66 13	43 27	47 19	28 13	44 13	69 23

"Assuming the intensity at the Cape as unity, we get the following formulæ for calculation:—

Def. N	$I' = \cdot4692 \operatorname{cosec} v' . w'$.
Def. S	$I' = \cdot4606 \operatorname{cosec} v' . w'$.
Mag. N and S	$I' = \cdot4686 \operatorname{cosec} v' . w'$.
Mag. N	$I' = \cdot4634 \operatorname{cosec} v' . w'$.
Mag. S	$I' = \cdot4552 \operatorname{cosec} v' . w'$.
Weight 1 grain	$I' = \cdot4728 \operatorname{cosec} v'$.
Weight $1\frac{1}{2}$ grain	$I' = \cdot6974 \operatorname{cosec} v'$.
Weight 2 grains	$I' = \cdot9361 \operatorname{cosec} v'$.

"The value of the intensity at King George's Sound by this needle is—

By weights	1·688.
By deflectors	1·672.

"The intensity by the other apparatus No. 1 is 1·688.

"At the Mauritius the intensity is—

By weights	1·156.
By deflectors	1·155.

And by the other instrument 1·156.

"It is therefore evident that needle B preserved its magnetism from King George's Sound to the Cape. Comparing the results with the deflectors with those of the other instrument, the deflectors do not appear to have lost magnetism; the difference at King George's Sound of ·01 arises probably from error of observation. As the results given by weights are the most accurate when the observations are made on land, they have been exclusively used in such cases; at sea both weights and deflectors have been used.

"Besides the correction for the effect of the ship's iron, a second correction for the effect of temperature on the needle and deflectors is necessary. The observations have all been reduced to a common temperature of 60° by means of the formulæ

$$c = I' . q(t' - t),$$

t being taken as 60° and q being the coefficient for 1° of FAHR. Values of q for each needle and deflector employed, were obtained at the Magnetic Observatory, Cape of Good Hope, in the usual manner. The following is an abstract of the observations:—

Needle or deflector.		Approximate distance.		Total deflection in scale divisions.	Mean alternation of temperature.	No. of alternations.	Corresponding mean difference of deflection.	Corresponding bifilar correction in parts of force when + additive.	Values of q.
		ft.	in.						
No. 1.	A. 1.	3	0	497·5	38° 35′	5	1·36	+·000046	·000072
	A. 2.	3	0	805·2	38 76	5	3·88	+·000004	·000116
	Def. N	1	0	873·3	40 43	5	4·33	·000019	·000123
	Def. S	1	0	880·5	40 02	5	2·82	·000054	·000081
C. 9.	A.	1	5	1019·0	34 68	3	4·21	—·000070	·000117
	B.	1	5	1059·5	43 35	4	3·18	—·000004	·000069
	C.	1	5	1065·9	43 46	5	3·67	+·000008	·000079
	Def. N	1	0	1004·8	45 85	5	7·08	+·000004	·000154
	Def. S	1	0	1021·7	47 38	5	6·45	—·000024	·000133

"From the values of q tables of corrections were formed; observing that when weights are used an increase of temperature gives an additive correction, and the contrary when the deflectors are used. As the values of q are small, and the greatest difference of temperature amounts only to 30°, the corrections are seldom of any importance; they have however always been applied.

"Besides the observations made on board the Pagoda, others have been laid down on the maps, in order to assist in drawing the magnetic lines. A series of observations made by Lieut. Smith, R.N., between the Cape and Van Diemen Island, and another by Lieut. Dayman, R.N., between Van Diemen Island and the Cape (with the *same* instrument), have been laid down on the map of the Inclination. The same needles and deflectors were used in both cases. Lieut. Smith's observations are all taken with the face of the instrument east; those of Lieut. Dayman's with it both east and west. The following observations, made at the Ross Bank Observatory, Van Diemen Island, will serve to obtain the index corrections; the inclination by the observatory needles being −70° 40′.

Observer.	Direct.	Def. N.	Def. S.	Def. N and S.	Mean.	Index correction.	Face of instrument.
Lieut. Smith.	−71° 39′	−71° 25′	−71° 19′	−71° 36′	−71° 28′	+48′	East
Lieut. Dayman.	−71 40	−71 22	−71 14	…………			
Lieut. Smith.	−70 54	−69 54	−70 42	…………	−70 20	−27	West
Lieut. Dayman.	−70 06	−70 09	−70 13				

"These corrections have been applied to all the observations made by Lieut. Smith*.

"As no observations were made for local attraction, we can only obtain approximate corrections, by comparing observations made on or near the same spot with the ship's head on different points of the compass. In the series made by Lieut. Smith we have the following observations:—

August 14.		August 18.		September 10.		September 13.	
E. ½ S. …………	−68° 09′	E. …………………	−67° 28′	S.W. ½ S. ………	−72° 41′	N. …………………	−72° 02′
S.E. by E. ½ E. …	−68 06	E. by S. …………	−67 32	N.N.W. …………	−73 03	N.N.E. …………	−72 09
S.S.E. …………	−68 02	E.S.E. …………	−67 38	N.W. ……………	−72 20		

"From these comparisons it would appear that the correction is very small, especially on the easterly points which were those generally observed upon; the observations have therefore been entered without any correction for the effect of the ship's iron.

"With regard to those of Lieut. Dayman, there are two cases where observations have been taken on different days, but in nearly the same position, and with the ship's head on different points of the compass, and also some in very nearly the same geographical position as the Pagoda. Comparing these, it appears that the effect of the iron is nearly the same in both ships; the observations have consequently been corrected from the Table that was used for those taken on board the Pagoda. The following comparisons will show how near these corrections approach the truth.

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* When observations have been made with the face both east and west, the correction becomes +10′; when weights as well as deflectors are used for the inclination, the correction face east and west becomes −13′; this has been applied to the observations made by Lieut. Dayman.

Lat.	Long.	Inclination.	Ship's head.	Tabular corrections.	Corrected Inclination.	Observer.	Remarks.
−35° 22′	117° 46′	−66° 06′	S. ½ E. N.N.W.	+0° 58′	−65° 08′	Lieut. DAYMAN.	Difference + 6′
−35 06	117 55	....	....	....	−65 14	Lieut. CLERK.	
−34 58	112 59	−66 47	N.W.	+1 31	−65 16	Lieut. DAYMAN.	Difference −32
−34 16	113 01	....	....	....	−64 44	Lieut. CLERK.	
−24 00	99 33	−55 32	W.N.W.	+1 12	−54 20	Lieut. DAYMAN.	Difference −13
−23 59	99 15	....	....	....	−54 07	Lieut. CLERK.	
−34 36	25 23	−57 01	S.W. ½ W.	+0 18	−56 43	Lieut. DAYMAN.	Difference +23
−34 31	27 04	....	....	....	−57 06	Lieut. CLERK.	
−34 48	19 33	−56 09	N. by W. ½ W.	+1 19	−54 50	Lieut. DAYMAN.	Difference +18
−35 07	20 46	....	....	....	−55 08	Lieut. CLERK.	
−36 42	118 35	−66 45	S.S.W.	−0 18	−67 03	Lieut. DAYMAN.	January 9, 1845.
−36 58	117 38	−68 41	N. by W.	+1 22	−67 19	Lieut. DAYMAN.	January 10, 1845.
−36 06	116 42	−66 09	S.S.W.	−0 18	−66 27	Lieut. DAYMAN.	January 11, 1845.
−36 24	115 33	−68 14	N.W.	+1 31	−66 43	Lieut. DAYMAN.	January 13, 1845.

"The observations thus corrected have been entered in the chart. The lines on the chart are drawn by estimation, so as to conform as nearly as possible with the observations: some part of the lines laid down by Lieut.-Colonel SABINE (in No. V. of the Contributions) from Sir JAMES C. ROSS's observations have been dotted in, to show the agreement of the two series.

"In the Chart of 'Magnetic Declinations,' a series of observations made on board the 'Erebus' by Sir JAMES C. ROSS, between the Cape of Good Hope and Hobarton, have been laid down. These observations have been corrected for index error and local attraction, in the same way as the other observations during the Antarctic Expedition, the same constants being used.

"In the chart of intensities, Sir JAMES C. ROSS's observations between the Cape of Good Hope and Hobarton have also been entered. These observations are contained in Lieut.-Colonel SABINE's Contributions, No. III. and V.. The Cape of Good Hope is the base station in this case; but the intensity there has been taken as 0·981; it is therefore necessary to reduce them to an intensity at the Cape = 1·0, in order that they may compare with the intensities taken on board the Pagoda; this is done by multiplying each of them by $\frac{\cdot 981}{1\cdot 000} = 1\cdot 02$ nearly. The observations thus corrected are given in a table at the end of the 'Pagoda' observations, together with those of variation and inclination by Sir J. ROSS, and the inclinations and intensities by Lieuts. SMITH and DAYMAN.

"In calculating the intensities observed by Lieut. SMITH, Hobarton has been taken as the base station, and the results by *weights only* used. The same has been done with the series by Lieut. Dayman, the weights of two grains and three grains having been observed daily; the following observations with weights made at the observatory, Hobarton, give the formulæ for calculation:—

$$\text{(I.) Lieut. Smith's.}\quad \left\{\begin{array}{ll} 2 \text{ grains } v=10^{\circ}\ 33' ; & I=1\cdot80;\ I'=\cdot3296 \text{ cosec } v'. \\ 3 \text{ grains } v=16\ \ 05 ; & I=1\cdot80;\ I'=\cdot4987 \text{ cosec } v'. \end{array}\right.$$

$$\text{(II.) Lieut. Dayman's.}\quad \left\{\begin{array}{l} 1 \text{ grain } v=\ 5\ \ 19 \\ 2 \text{ grains } v=10\ \ 35 \\ 3 \text{ grains } v=16\ \ 20 \\ 4 \text{ grains } v=21\ \ 50 \\ 5 \text{ grains } v=27\ \ 41 \\ 6 \text{ grains } v=34\ \ 08 \end{array}\right\}$$

From these we obtain the following values of v for 2 and 3 grains; viz.—

for 2 grains $v=10^{\circ}\ 43'$.

for 3 grains $v=16\ \ 11$.

Hence for 2 grains $I'=\cdot3347$ cosec v'.

for 3 grains $I'=\cdot5017$ cosec v'.

"In correcting these observations the same plan has been pursued as with the dip observations. As Lieut. Smith's observations required no correction in the latter case, so none has been applied to the intensities; and Lieut. Dayman's have been corrected from the same table as was used for the 'Pagoda' observations. No corrections have been applied for the effect of temperature; but they are probably so small as not to affect the results."

Observations of the Declination made on board Her Majesty's hired Bark "Pagoda," from the 10th of January to the 23rd of June 1845.

The Observers are distinguished as follows:—M. Lieut. Moore; B. Mr. Bodie, Master; Cl. Lieut. Clerk; Cm. Mr. Comber, Mate; T. Mr. Tufnell, and Bn. Mr. Burdon, Midshipmen. West Declination characterized by the sign +.

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845. Jan. 10 A.M.	−34° 42′	17° 36′	M.	+29° 04′	W.	−53° 15′	+16′	+47′	+30° 07′	+29° 51′	Card A. Index correction +47′ by observations made at the observatory, Cape of Good Hope.
	−34 42	17 36	M.	+29 12	W.		+16	+47	+30 15		
	−34 42	17 36	M.	+28 50	W. ½ S.		+15	+47	+29 52		
	−34 42	17 36	Cl.	+28 06	W.		+16	+47	+29 09		
11 A.M.	−35 26	15 08	Cl.	+27 31	W.S.W.	−51 27	+11	+47	+28 29	+28 39	
	−35 26	15 08	M.	+27 51	W.S.W.		+11	+47	+28 49		
	−35 26	15 08	Cl.	+27 43	W.S.W.		+11	+47	+28 41		
	−35 26	15 08	M.	+27 41	S.W.byW.¼W.		+10	+47	+28 38		
12 A.M.	−35 17	14 00	B.	+25 45	W. by N.	−51 16	+03	+47	+26 35	+27 15	
	−35 17	14 00	B.	+26 23	W. by N.		+03	+47	+27 13		
	−35 17	14 00	B.	+27 06	W. by N.		+03	+47	+27 56		
13 A.M.	−35 10	13 25	B.	+24 37	S.W. by W.	−51 27	+07	+47	+25 31	+25 40	
	−35 10	13 25	B.	+25 04	S.W. by W.		+07	+47	+25 58		
	−35 10	13 25	B.	+24 38	S.W. by W.		+07	+47	+25 32		
15 P.M.	−38 43	14 25	M.	+24 22	S.S.W. ½ W.	−53 05	00	+47	+25 09	+25 09	
16 A.M.	−39 00	14 38	M.	+27 13	S.W.byW.½W.	−54 13	+18	+47	+28 18	+28 20	
	−39 01	14 45	Cm.	+25 44	S.W. by S.		+06	+47	+26 37		
16 P.M.	−39 12	14 42	M.	+27 48	S.W. by S.		+06	+47	+28 41		
	−39 20	14 12	M.	+28 25	S.W. by S.		+06	+47	+29 18		
	−39 22	14 25	B.	+27 10	S.W. by S.		+06	+47	+28 03		
	−39 22	14 25	B.	+28 28	S.W. by S.		+06	+47	+29 21		
	−39 22	14 25	B.	+27 01	S.W. by S.		+06	+47	+27 54		
	−39 22	14 25	B.	+27 49	S.W. by S.		+06	+47	+28 42		
	−39 22	14 25	B.	+27 28	S.W. by S.		+06	+47	+28 21		
	−39 22	14 25	B.	+28 28	S.W. by S.		+06	+47	+29 21		
	−39 22	14 25	Cm.	+26 26	S.W. by S.		+06	+47	+27 19		
17 A.M.	−40 08	14 32	B.	+26 17	S.W. by W.	−55 05	+16	+47	+27 20	+27 40	
	−40 08	14 32	B.	+25 18	S.W. by W.		+16	+47	+26 21		
	−40 09	14 33	M.	+25 33	S.W. by W.		+16	+47	+26 36		
	−40 12	14 39	Cl.	+26 56	S.W. by W.		+16	+47	+27 59		
	−40 16	14 36	T.	+27 34	S.W. by W.		+16	+47	+28 37		
	−40 18	14 35	T.	+26 54	S.W. by W.		+16	+47	+27 57		
	−40 15	14 37	Cm.	+27 04	S.W. by W.		+16	+47	+28 07		
	−40 15	14 37	Cm.	+27 12	S.W. by W.		+16	+47	+28 15		
	−40 14	14 37	Cm.	+26 00	S.W. by W.		+16	+47	+27 03		
	−40 15	14 38	T.	+26 00	S.W. by W.		+16	+47	+27 03		
	−40 24	14 32	M.	+27 57	S.W. by W.		+16	+47	+29 00		
19 A.M.	−44 45	13 19	Cl.	+25 09	S.S.W. ½ W.	−56 14	+04	+47	+26 00	+26 34	Ship very unsteady; heavy sea.
	−44 45	13 19	M.	+23 05	S.S.W. ½ W.		+04	+47	+23 56		
	−44 45	13 19	B.	+27 40	S.S.W.		+02	+47	+28 29		
	−44 45	13 19	Cm.	+27 00	S.S.W.		+02	+47	+27 49		
20 A.M.	−46 24	13 34	B.	+24 51	S.W. by W.	−56 08	+19	+47	+25 57	+25 54	
	−46 24	13 34	B.	+24 31	S.W. by W.		+19	+47	+25 37		
	−46 24	13 34	B.	+25 02	S.W. by W.		+19	+47	+26 08		
22 A.M.	−48 27	10 51	B.	+23 08	S.W. by S.	−56 44	+12	+47	+24 07	+24 50	
	−48 27	10 51	B.	+22 41	S.W. by S.		+12	+47	+23 40		
	−48 27	10 51	M.	+24 40	S.W. by S.		+12	+47	+25 39		
	−48 27	10 51	Cl.	+24 54	S.W. by S.		+12	+47	+25 53		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		° ′	° ′	′	° ′	° ′	
Jan. 23 A.M.	−50 30	10 25	M.	+22 30	s.w. ½ s.	−57 11	+ 16	+47	+23 33	+23 55	
	−50 31	10 25	Cm.	+23 38	s.w. by s.		+ 16	+47	+24 41		
	−50 31	10 25	Cl.	+24 27	s.w. ½ s.		+ 16	+47	+25 30		
23 P.M.	−50 48	10 17	M.	+23 18	s.w.byw.½w.		+ 16	+47	+24 21		
	−50 50	10 20	Cl.	+21 09	s.w. by w.		+ 16	+47	+22 12		
	−50 58	10 10	M.	+23 14	s.w.		+ 16	+47	+24 17		
	−50 58	10 10	Cl.	+22 26	s.w.		+ 16	+47	+23 29		
	−50 58	10 09	T.	+22 15	s.w.		+ 16	+47	+23 18		
24 A.M.	−51 45	9 34	B.	+23 11	s.w. by w.	−57 39	+ 25	+47	+24 23	+22 37	
	−51 45	9 34	M.	+20 06	s.w. by w.		+ 25	+47	+21 18		
	−51 45	9 34	Cl.	+20 58	s.w. by w.		+ 25	+47	+22 10		
24 P.M.	−51 47	9 34	Cm.	+22 00	s.w.byw.½w.	−57 39	+ 29	+47	+23 16	+23 46	Card A.
	−51 47	9 34	Cm.	+23 50	s.w.byw.½w.		+ 29	+47	+25 06		
	−51 47	9 34	Cm.	+24 04	s.w.byw.½w.		+ 29	+47	+25 20		
	−51 47	9 40	Bn.	+22 50	s.w.byw.½w.		+ 29	+47	+24 06		
	−51 45	9 34	B.	+23 11	s.w. by w.		+ 25	+47	+24 23		
	−51 45	9 34	M.	+20 06	s.w. by w.		+ 25	+47	+21 18		
	−51 45	9 34	Cl.	+20 58	s.w. by w.		+ 25	+47	+22 10		
	−51 49	9 32	Cl.	+22 46	s.w. by w.		+ 25	+47	+23 58		
	−51 49	9 32	B.	+21 49	s.w. by w.		+ 25	+47	+23 01		
	−51 50	9 32	B.	+22 53	s.w.byw.½w.		+ 29	+47	+24 09		
	−51 50	9 31	Cl.	+22 18	s.w.byw.½w.		+ 29	+47	+23 34		
	−51 50	9 31	M.	+22 49	s.w.byw.½w.		+ 29	+47	+24 05		
	−51 50	9 31	Cl.	+23 08	s.w.byw.½w.		+ 29	+47	+24 24		
	−51 50	9 31	T.	+22 36	s.w.byw.½w.		+ 29	+47	+23 52		
25 A.M.	−52 45	7 53	M.	+22 21	s.w.byw.½w.	−57 14	+ 29	+47	+23 37	+23 46	Card A.
	−53 00	7 53	Cm.	+22 50	s w. by w.		+ 25	+47	+24 02		
	−53 00	7 53	Cm.	+22 06	s.w. by w.		+ 25	+47	+23 18		
	−53 00	7 53	Cm.	+22 54	s.w. by w.		+ 25	+47	+24 06		
26 A.M.	−53 52	6 16	M.	+19 49	w. ½ n.	−57 00	+ 36	+52	+21 17	+21 34	Card J. Compass steady. Index correction +52′ by observations made at the Magnetic Observatory, Cape of Good Hope.
	−53 52	6 16	B.	+20 18	w. ½ n.		+ 36	+52	+21 46		
	−53 52	6 16	Cl.	+20 56	w. by s.		+ 33	+52	+22 21		
	−53 52	6 16	Cl.	+20 24	w. by s.		+ 33	+52	+21 49		
	−53 52	6 16	Cl.	+20 36	w. by s.		+ 33	+52	+22 01		
	−53 52	6 16	Bn.	+21 28	w. by s.		+ 33	+52	+22 53		
	−53 52	6 16	Cm.	+20 36	w. by s.		+ 33	+52	+22 01		
26 P.M.	−53 55	6 06	B.	+21 08	e. ½ s.		−1 22	+52	+20 38		
	−53 55	6 06	Cl.	+21 38	e. ½ s.		−1 22	+52	+21 08		
	−53 55	6 06	Cl.	+20 54	n.e.		−1 17	+52	+20 29		
	−53 55	6 06	Cl.	+20 53	n.		− 51	+52	+20 54		
	−53 55	6 06	M.	+22 03	e. ½ s.		−1 22	+52	+21 33		
27 P.M.	−55 13	5 57	M.	+19 56	s.w. by s. ½ s.	−57 49	+ 12	+52	+21 00	+21 23	Card unsteady.
	−55 30	5 54	M.	+21 14	s.s.w. ½ w.		+ 10	+52	+22 16		
	−55 45	5 50	M.	+19 48	s.w. by s.		+ 12	+52	+20 52		
29 A.M.	−58 53	4 19	Cl.	+16 07	s.w. ½ s.	−59 00	+ 19	+52	+17 18	+17 30	Card unsteady.
	−58 53	4 19	B.	+13 45	s.w. by s.		+ 19	+52	+14 56		
29 P.M.	−59 13	4 00	M.	+15 36	s.w. ½ s.		+ 19	+52	+16 47		
	−59 13	4 00	Cl.	+19 48	s.w. ½ s.		+ 19	+52	+20 59		
31 A.M.	−60 48	8 18	B.	+22 35	e. ½ s.	−61 30	−1 47	+52	+21 40	+20 29	Unsteady.
	−61 03	9 05	Cm.	+20 32	s.e. by s.		− 48	+52	+20 36		
	−61 08	9 05	M.	+19 27	s.e. by s.		− 48	+52	+19 31		
	−61 08	9 05	Cl.	+19 43	s.e. by s.		− 48	+52	+19 47		
31 P.M.	−61 15	9 30	Cl.	+20 31	s.e.		−1 01	+52	+20 22		
	−61 15	9 30	M.	+21 08	s.e.		−1 01	+52	+20 59		
	−61 20	10 07	M.	+21 16	s.s.e. ½ e.		− 31	+52	+21 37		
	−61 20	10 07	Cl.	+20 28	s.s.e. ½ e.		− 31	+52	+20 49		
	−61 20	10 07	Bn.	+19 23	s.s.e. ½ e.		− 31	+52	+19 44		
	−61 20	10 07	Cl.	+19 21	s.s.e. ½ e.		− 31	+52	+19 42		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		° ′	° ′	′	° ′	° ′	
Feb. 1 A.M.	—61 55	12 26	Cl.	+22 15	s.e. by s.	—63 17	— 48	+52	+22 19	+22 07	Very unsteady.
1 P.M.	—62 06	12 45	Cm.	+23 40	s.e. by s.		— 48	+52	+23 44		
	—62 06	12 55	B.	+22 21	s.e. by s.		— 48	+52	+22 25		
	—62 06	12 55	Cl.	+20 12	s.e.		—1 04	+52	+20 00		
2 A.M.	—61 53	15 57	B.	+22 55	e.n.e.	—63 28	—2 00	+52	+21 47	+23 11	Unsteady.
2 P.M.	—61 54	16 34	M.	+25 19	s.e. ½ e.		—1 10	+52	+25 01		
	—61 54	16 38	M.	+26 34	s.e. ½ e.		—1 10	+52	+26 16		
	—61 55	16 40	T.	+23 04	s.e. ½ e.		—1 10	+52	+22 46		
	—61 54	16 42	Cl.	+21 28	s.e. by e.		—1 18	+52	+21 02		
	—61 54	16 57	Cl.	+21 36	s.e. ½ e.		—1 10	+52	+21 18		
	—61 54	16 57	B.	+20 12	s.e. ½ e.		—1 10	+52	+19 54		
	—61 54	16 57	Bn.	+27 44	s.e. ½ e.		—1 10	+52	+27 26		
3 A.M.	—61 49	19 15	T.	+27 56	e.s.e.	—64 20	—1 44	+52	+27 04	+26 34	A less delicate point was used for the suspension of the compass-card, which made it much steadier.
	—61 49	19 15	Bn.	+25 32	s.e. by e. ½ e.		—1 36	+52	+24 48		
	—61 50	19 15	Cm.	+27 32	s.e. by e. ½ e.		—1 36	+52	+26 48		
	—61 50	19 06	B.	+27 19	e.s.e.		—1 44	+52	+26 27		
	—61 50	19 12	M.	+27 41	e.s.e.		—1 44	+52	+26 49		
	—61 50	19 13	M.	+27 43	e.s.e.		—1 44	+52	+26 51		
	—61 50	19 14	M.	+27 15	e. by s.		—2 03	+52	+26 04		
	—61 50	19 13	Cl.	+27 56	e.s.e.		—1 44	+52	+27 04		
	—61 50	19 13	Cl.	+27 59	e.s.e.		—1 44	+52	+27 07		
	—61 50	19 13	Bn.	+27 32	e.s.e.		—1 44	+52	+26 40		
3 P.M.	—61 50	19 14	M.	+26 52	n.e. by n.	—64 20	—1 34	+52	+26 10	+26 16	Card steady. Being a calm the declinations were observed on different points of the compass to obtain the effect of the ship's iron. The compass was afterwards placed in a copper-fastened boat and the declination observed at a distance from the ship.
	—61 50	19 14	Cl.	+24 05	n.w. ½ w.		+ 21	+52	+25 18		
	—61 50	19 14	Cl.	+23 31	w. by n.		+1 00	+52	+25 23		
	—61 50	19 14	Cl.	+23 24	w. by s.		+1 10	+52	+25 26		
	—61 50	19 14	Cl.	+23 31	w.s.w.		+1 07	+52	+25 30		
	—61 50	19 14	Cl.	+24 37	n.w. by w.		+ 29	+52	+25 58		
	—61 50	19 14	B.	+25 37	n.w.		+ 12	+52	+26 41		
	—61 50	19 14	Cl.	+24 52	n.w.		+ 12	+52	+25 56		
	—61 50	19 14	Cl.	+24 00	w. by n.		+1 00	+52	+25 52		
	—61 50	19 14	M.	+24 06	w.		+1 13	+52	+26 11		
	—61 50	19 14	M.	+23 51	w.		+1 13	+52	+25 56		
	—61 50	19 14	Cl.	+25 46	w.s.w.		+1 07	+52	+27 45		
	—61 50	19 14	Cl.	+23 53	s.w.		+ 48	+52	+25 33		
	—61 50	19 14	Cl.	+28 55	s.s.e.		— 35	+52	+29 12		
	—61 50	19 14	M.	+25 55	s. ½ e.		— 11	+52	+26 36		
	—61 50	19 14	M.	+24 45*	In the boat.		....	+52	+25 37		
	—61 50	19 14	M.	+27 03	s. by e.		— 19	+52	+27 36		
4 A.M.	—62 00	20 55	M.	+25 36	s. ½ e.	—64 40	— 11	+52	+26 17	+28 05	Compass steady.
	—62 00	20 55	M.	+26 09	s. ½ e.		— 11	+52	+26 50		
	—62 00	20 37	Cl.	+26 59	s. ½ e.		— 11	+52	+27 40		
4 P.M.	—62 05	20 58	M.	+29 02	s.s.e. ½ e.		— 44	+52	+29 10		
	—62 07	21 04	M.	+27 14	s.s.e.		— 35	+52	+27 31		
	—62 10	21 03	Cl.	+28 15	s.s.e.		— 35	+52	+28 32		
	—62 10	21 03	Cl.	+28 16	s.s.e.		— 35	+52	+28 33		
	—62 10	21 03	Bn.	+30 14	s.s.e.		— 35	+52	+30 31		
	—62 10	21 03	B.	+27 26	s.s.e.		— 35	+52	+27 43		
5 A.M.	—63 14	21 10	M.	+29 01	s. by e.	—65 35	— 19	+52	+29 34	+28 56	Steady.
	—63 18	21 10	M.	+28 51	s. by e.		— 19	+52	+29 24		
	—63 18	21 10	Cl.	+27 08	s. ½ e.		— 11	+52	+27 49		
	—63 18	21 10	Bn.	+28 47	s. ½ e.		— 11	+52	+29 28		
	—63 18	21 10	T.	+28 08	s. ½ e.		— 11	+52	+28 49		
5 P.M.	—63 19	21 10	M.	+28 14	s.s.e.		— 35	+52	+28 31		

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* This observation is not much to be depended on, as the compass was very unsteady and difficult to observe.

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		° ′	° ′	′	° ′	° ′	
Feb. 6 A.M.	−64 06	23 17	B.	+28 41	S.S.E.	−66 39	− 42	+52	+28 51	+30 24	Card steady.
	−64 18	24 05	Cl.	+28 29	S.S.E.		− 42	+52	+28 39		
	−64 18	24 05	Cl.	+29 44	S.S.E.		− 42	+52	+29 54		
	−64 20	24 02	M.	+29 57	S.S.E.		− 42	+52	+30 07		
	−64 25	24 10	M.	+28 43	S.S.E. ½ E.		− 48	+52	+28 47		
6 P.M.	−64 35	26 30	Cl.	+31 43	S.E. by S. ½ S.		− 50	+52	+31 45		
	−64 38	26 35	Cl.	+31 22	S.S.E.		− 42	+52	+31 32		
	−64 38	26 35	Bn.	+32 39	S.S.E.		− 42	+52	+32 49		
	−64 25	26 28	M.	+31 06	S.S.E. ½ E.		− 48	+52	+31 10		
7 A.M.	−65 30	28 32	M.	+32 02	S.E. by S.	−67 28	−1 03	+52	+31 51	+31 37	Compass steady.
	−65 25	27 45	B.	+32 46	S.S.E.		− 42	+52	+32 56		
	−65 16	27 45	Cl.	+30 41	S.S.E. ½ E.		− 52	+52	+30 41		
	−65 16	27 45	Cl.	+31 16	S.S.E. ½ E.		− 52	+52	+31 16		
	−65 16	27 45	Bn.	+31 51	S.S.E. ½ E.		− 52	+52	+31 51		
7 P.M.	−66 02	29 05	B.	+31 12	S. ½ E.		− 18	+52	+31 46		
	−66 02	29 05	Cl.	+30 11	S. ½ E.		− 18	+52	+30 45		
	−66 02	29 05	M.	+30 25	S. ½ E.		− 18	+52	+30 59		
	−66 02	29 05	B.	+31 08	S. ½ E.		− 18	+52	+31 42		
	−66 02	29 05	Bn.	+31 00	S. ½ E.		− 18	+52	+31 34		
	−66 02	29 05	Cl.	+31 49	S. ½ E.		− 18	+52	+32 23		
9 P.M.	−66 26	37 25	Cl.	+36 04	S.E. by E.	−68 49	−1 08	+52	+35 48	+35 39	Steady.
	−66 26	37 25	Bn.	+35 08	S.E. by E.		−1 08	+52	+34 52		
	−66 26	37 25	M.	+36 34	S.E. by E.		−1 08	+52	+36 18		
10 A.M.	−66 43	38 32	B.	+37 20	S. by W. ½ W.	−69 22	+ 32	+52	+38 44	+37 43	Steady.
	−66 43	38 32	Cl.	+35 26	S.S.W.		+ 42	+52	+37 00		
10 P.M.	−67 03	38 32	Bn.	+34 23	S.S.W. ½ W.		+ 52	+52	+36 07		
	−67 03	38 32	Cl.	+35 10	S.S.W. ½ W.		+ 52	+52	+36 54		
	−67 03	38 32	Cl.	+39 35	N. by W.		− 36	+52	+39 51		
11 A.M.	−67 34	39 41	Bn.	+40 06	E.	−69 38	−2 46	+52	+38 12	+38 13	Card steady.
	−67 34	39 41	Cl.	+40 11	E. by S.		−2 30	+52	+38 33		
	−67 34	39 41	Cl.	+39 26	E. by S.		−2 30	+52	+37 48		
	−67 34	39 41	Cl.	+36 03	S.W. by S.		+1 00	+52	+37 55		
	−67 34	39 41	Cl.	+37 37	S.		− 02	+52	+38 31		
	−67 34	39 41	Cl.	+38 57	N.N.E.		−1 40	+52	+38 09		
	−67 38	39 41	B.	+37 49	S. ½ E.		− 15	+52	+38 26		
12 A.M.	−66 38	39 23	B.	+37 23	N. by E.	−70 16	−1 20	+47	+36 50	+37 18	Card A. unsteady.
	−66 38	39 23	Cl.	+39 04	S.S.E.		− 45	+47	+39 06		
	−66 47	39 20	M.	+35 56	S.S.E.		− 45	+47	+35 58		
13 A.M.	−67 06	40 03	Cl.	+37 48	N.E. ½ E.	−69 35	−2 20	+52	+36 20	+36 59	Card J. steady.
	−67 06	40 03	Cl.	+38 57	N.E. by E.		−2 26	+52	+37 23		
	−67 06	40 03	T.	+39 30	N.E. by E.		−2 26	+52	+37 56		
	−67 06	40 03	Bn.	+38 03	N.E. by E.		−2 26	+52	+36 29		
	−67 06	40 03	B.	+38 25	N.E. by E. ½ E.		−2 32	+52	+36 45		
14 A.M.	−67 01	40 30	B.	+35 53	N.N.E.	−69 15	−1 35	+52	+35 10	+37 12	Very unsteady.
	−67 01	40 30	Cl.	+40 02	N.N.E. ½ E.		−1 41	+52	+39 13		
16 A.M.	−64 52	38 35	M.	+36 11	S. by E.	−68 47	− 22	+52	+36 41	+36 38	Compass unsteady.
	−64 52	38 35	Cl.	+41 36	N.N.E.		−1 37	+52	+40 51		
16 P.M.	−64 52	38 37	Cl.	+35 44	S.E.		−1 28	+52	+35 08		
	−64 52	38 37	T.	+36 06	E.S.E.		−2 03	+52	+34 55		
	−64 52	38 37	Bn.	+36 31	S.E. by E.		−1 46	+52	+35 37		
17 P.M.	−64 52	40 12	M.	+37 00	S.S.E.	−68 31	− 44	+52	+37 08	+36 54	Steady.
	−64 52	40 12	Bn.	+35 28	S.S.E.		− 44	+52	+35 36		
	−64 52	40 12	M.	+37 41	S.S.E.		− 44	+52	+37 49		
	−64 52	40 12	Cl.	+38 20	S.S.E.		− 44	+52	+38 28		
	−64 52	40 12	Cl.	+37 54	S.E. by S.		−1 06	+52	+37 40		
	−64 52	40 12	T.	+34 54	S.E. by S.		−1 06	+52	+34 40		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845. Feb. 18 A.M.	−64° 22′	40° 49′	Cl.	+38° 35′	S. by E. ½ E.	−68° 40′	−° 32′	+52′	+38° 55′	+36° 32′	Very unsteady.
	−64 22	40 49	B.	+34 41	N. by E. ½ E.		−1 24	+52	+34 09		
19 P.M.	−63 58	41 25	Cl.	+38 43	S.E. by E. ½ E.	−69 49	−2 04	+52	+37 31	+37 34	Very unsteady.
	−63 58	41 25	Bn.	+38 20	E.S.E.		−2 15	+52	+36 57		
	−63 56	42 00	Bn.	+39 52	E. by S.		−2 30	+52	+38 14		
20 A.M.	−63 24	44 47	B.	+40 08	S.E. by S.	−70 09	−1 08	+52	+39 52	+39 39	Unsteady.
	−63 24	45 32	Cl.	+41 03	S.E. by E. ½ E.		−2 04	+52	+39 51		
	−63 22	45 32	Bn.	+42 12	S.E. by E. ½ E.		−2 04	+52	+41 00		
	−63 22	45 32	Cm.	+39 39	S.E. by E. ½ E.		−2 04	+52	+38 27		
20 P.M.	−63 19	45 52	M.	+39 50	S.E. by E.		−1 54	+52	+38 48		
	−63 19	45 52	Cl.	+40 11	S.E. by S.		−1 08	+52	+39 55		
21 A.M.	−63 34	46 48	M.	+39 46	E. by S. ½ S.	−70 08	−2 28	+52	+38 10	+40 03	Card steady.
	−63 34	46 48	Cl.	+39 00	S.S.E.		− 49	+52	+39 03		
	−63 34	46 48	Cl.	+39 20	S.S.E.		− 49	+52	+39 23		
21 P.M.	−63 40	47 03	M.	+40 22	S.E. ½ S.		−1 01	+52	+40 13		
	−63 41	47 24	B.	+42 45	S.E.		−1 37	+52	+42 00		
	−63 38	46 56	Cl.	+41 11	S.E.		−1 37	+52	+40 26		
	−63 41	47 24	Cl.	+41 50	S.E.		−1 37	+52	+41 05		
22 P.M.	−63 43	49 29	Cl.	+35 00	S.S.W. ½ W.	−70 00	+ 51	+52	+36 43	+39 21	Very unsteady.
	−63 43	49 29	M.	+41 31	S. by E.		− 24	+52	+41 59		
25 A.M.	−61 36	52 56	B.	+41 03	E. ½ N.	−70 48	−2 51	+52	+39 04	+40 30	Card steady.
	−61 36	52 56	Cl.	+41 40	E.		−2 57	+52	+39 35		
	−61 36	52 56	Bn.	+42 45	E.		−2 57	+52	+40 40		
25 P.M.	−61 30	53 43	M.	+40 31	S.E. by E.		−2 00	+52	+39 23		
	−61 30	55 13	Cl.	+43 14	S.E. by S.		−1 13	+52	+42 53		
	−61 28	55 14	M.	+42 30	S.E. ½ E.		−1 56	+52	+41 26		
26 A.M.	−61 19	56 52	B.	+42 44	S.	−71 44	+ 03	+52	+43 39	+41 57	Very unsteady.
	−61 19	57 26	M.	+43 56	S.E. ½ E.		−1 57	+52	+42 51		
	−61 19	57 30	M.	+42 00	S.E. ½ E.		−1 57	+52	+40 55		
	−61 17	57 18	Cl.	+42 11	S.E. ½ E.		−1 57	+52	+41 06		
26 P.M.	−61 17	58 30	Cl.	+43 29	S.E.		−1 46	+52	+42 35		
	−61 17	58 30	M.	+41 42	S.E. ½ E.		−1 57	+52	+40 37		
27 A.M.	−61 02	62 55	B.	+46 08	E.	−72 53	−3 21	+52	+43 39	+45 17	Very unsteady.
	−61 02	62 55	Bn.	+46 02	S.E. ½ S.		−1 40	+52	+45 14		
	−61 02	64 10	M.	+47 17	S.E. ½ S.		−1 40	+52	+46 29		
27 P.M.	−61 10	65 00	Cl.	+45 48	S.S.E.		− 56	+52	+45 44		
28 P.M.	−61 43	69 36	M.	+46 00	S.S.E.	−73 50	−1 01	+52	+45 51	+45 51	Steady.
March 1 A.M.	−62 10	72 24	Cl.	+46 09	S.S.E.	−74 34	−1 02	+52	+45 59	+46 01	Compass steady.
	−62 10	72 24	T.	+46 04	S.S.E.		−1 02	+52	+45 54		
1 P.M.	−62 10	72 25	M.	+46 19	S.S.E. ½ E.		−1 19	+52	+45 52		
	−62 10	72 26	M.	+47 55	S.E. by E.		−2 36	+52	+46 11		
	−62 10	72 26	Cl.	+46 07	S.S.E. ½ E.		−1 19	+52	+45 40		
	−62 10	72 26	Cl.	+46 12	S.S.E. ½ E.		−1 19	+52	+45 45		
	−62 10	72 26	Cl.	+47 31	S.E. by S.		−1 37	+52	+46 46		
2 A.M.	−62 36	75 42	B.	+50 57	S. ½ E.	−74 58	− 10	+52	+51 39	+50 35	Card steady.
	−62 43	76 05	M.	+49 39	S. ½ E.		− 10	+52	+50 21		
	−62 43	76 05	Cl.	+49 31	S. by E.		− 28	+52	+49 55		
	−62 43	76 05	Cl.	+49 10	S.		+ 28	+52	+50 10		
	−62 43	76 05	Cm.	+49 50	S. by E.		− 28	+52	+50 14		
2 P.M.	−62 46	76 50	M.	+49 52	S. ½ E.		− 10	+52	+50 34		
	−62 46	76 50	T.	+48 18	S. ½ E.		− 10	+52	+49 00		
	−62 46	76 50	Cl.	+48 37	S. ¾ E.		− 19	+52	+49 10		
	−62 54	76 59	B.	+50 33	S.		+ 08	+52	+51 33		
	−62 54	76 59	Cl.	+50 17	S.		+ 08	+52	+51 17		
	−62 54	76 59	Bn.	+51 31	S.		+ 08	+52	+52 31		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845. March 4 A.M.	−63° 05′	80° 20′	Cl.	+55° 33′	E. ½ N.	−76° 20′	−4° 08′	+52′	+52° 17′	+52° 17′	Very unsteady.
5 A.M.	−61 41	84 50	M.	+50 48	S.E. ½ S.	−76 43	−2 27	+52	+49 13	+47 19	Unsteady.
	−61 42	84 50	B.	+49 37	S.E.		−2 36	+52	+47 53		
	−61 41	84 50	Cl.	+52 14	S.E.		−2 36	+52	+50 30		
	−61 41	84 50	T.	+49 55	S.E.		−2 36	+52	+48 11		
5 P.M.	−61 41	85 59	Cl.	+47 11	S.E. ½ S.		−2 27	+52	+45 36		
	−61 41	85 59	B.	+46 36	S.E. ½ S.		−2 27	+52	+45 01		
	−61 41	85 59	M.	+46 24	S.E. ½ S.		−2 27	+52	+44 49		
6 A.M.	−60 51	87 20	B.	+52 54	N.E.	−77 04	−3 38	+52	+50 08	+47 47	Compass unsteady.
	−60 51	87 20	Bn.	+49 16	E.		−4 32	+52	+45 36		
	−60 48	88 23	Cl.	+49 25	S.E.		−2 40	+52	+47 37		
7 A.M.	−61 10	90 26	B.	+50 52	S.S.E.	−77 38	−1 20	+52	+50 24	+49 28	Unsteady.
	−61 20	91 00	M.	+50 04	S. by E.		− 30	+52	+50 26		
	−61 20	91 00	Cl.	+47 29	S. ¼ W.		+ 34	+52	+48 55		
	−61 20	91 00	Cl.	+46 47	S. ½ E.		− 20	+52	+47 19		
	−61 20	91 00	T.	+48 53	S.		+ 15	+52	+50 00		
7 P.M.	−61 28	91 58	Cl.	+45 22	S.W. by S.		+2 13	+52	+48 27		
	−61 28	91 58	Cl.	+46 48	S.W. by S.		+2 13	+52	+49 53		
	−61 28	91 58	Bn.	+46 32	S.W. by S. ½ S.		+2 00	+52	+49 24		
	−61 28	91 58	M.	+46 19	S.S.W.		+1 38	+52	+48 49		
	−61 30	92 00	B.	+48 30	S.S.W.		+1 38	+52	+51 00		Amplitude.
8 A.M.	−61 27	91 32	Bn.	+53 20	E.S.E.	−77 57	−4 11	+52	+50 01	+49 02	Card steady.
	−61 27	91 32	B.	+52 57	E.S.E ¼ E.		−4 15	+52	+49 34		
	−61 27	91 32	Bn.	+51 53	E.S.E.		−4 11	+52	+48 34		
	−61 15	92 00	Cl.	+53 18	E. by N.		−4 20	+52	+49 50		
8 P.M.	−61 03	91 49	B.	+52 26	E.		−4 46	+52	+48 32		
	−61 03	91 49	B.	+51 01	E.N.E.		−4 34	+52	+47 19		
	−61 03	91 49	T.	+52 54	E. by S.		−4 23	+52	+49 23		
9 A.M.	−60 58	92 02	B.	+48 53	E.N.E.	−77 32	−4 34	+52	+45 11	+48 01	Compass unsteady.
	−60 58	92 02	Bn.	+52 21	N.E. by E.		−4 10	+52	+49 03		
	−60 58	92 04	Bn.	+52 42	E.N.E.		−4 34	+52	+49 00		
	−60 50	92 10	B.	+52 59	E.N.E.		−4 34	+52	+49 17		
	−60 30	92 27	M.	+51 50	E.		−4 46	+52	+47 56		
9 P.M.	−60 22	93 17	B.	+51 00	E.S.E.		−4 11	+52	+47 41		
10 A.M.	−60 03	94 00	Bn.	+48 09	E. by S. ½ S.	−77 37	−4 20	+52	+44 41	+44 53	Unsteady.
	−60 03	94 01	B.	+46 11	E. by S.		−4 23	+52	+42 40		
10 P.M.	−60 03	96 30	M.	+48 10	S.E.		−2 49	+52	+46 13		
	−60 03	96 30	Cl.	+47 54	S.E.		−2 49	+52	+45 57		
11 A.M.	−60 01	99 10	B.	+38 42	S.E. by S.	−79 31	−2 26	+52	+37 08	+41 02	Very unsteady.
11 P.M.	−59 31	100 45	Cl.	+44 46	N.E. ½ E.		−4 54	+52	+40 44		
	−59 31	100 45	M.	+43 03	N. ½ E.		−1 46	+52	+42 09		
	−59 31	100 45	Cl.	+44 20	N. ½ E.		−1 46	+52	+43 26		
	−59 31	100 45	T.	+41 02	N. ½ E.		−1 46	+52	+40 08		
	−59 31	100 45	B.	+40 27	N. ½ E.		−1 46	+52	+39 33		
	−59 31	100 45	Cl.	+45 55	N. by E. ½ E.		−2 38	+52	+44 09		
12 A.M.	−58 31	98 59	Cl.	+42 31	N.E. by N.	−78 50	−3 33	+52	+39 50	+39 50	Very unsteady.
13 A.M.	−58 30	98 32	B.	+46 56	N.E. by E. ½ E.	−78 10	−4 58	+52	+42 50	+40 37	Very unsteady.
	−58 30	98 32	Cl.	+42 58	E.N.E.		−4 58	+52	+38 52		
13 P.M.	−58 30	98 32	Cl.	+43 51	E. ½ S.		−4 33	+52	+40 10		
14 A.M.	−56 56	101 10	M.	+40 48	E.S.E.	−78 26	−4 02	+52	+37 38	+37 37	Very unsteady.
	−56 50	101 20	Cl.	+40 46	E.S.E.		−4 02	+52	+37 36		
15 A.M.	−55 50	103 08	Cl.	+36 52	E. by N.	−78 33	−5 01	+52	+32 43	+32 54	Very unsteady.
15 P.M.	−55 40	103 18	M.	+35 37	E. ½ S.		−4 33	+52	+31 56		
	−55 35	103 20	Cl.	+37 56	E. by S.		−4 46	+52	+34 02		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		° ′	° ′	′	° ′	° ′	
Mar. 16 A.M.	−55 15	106 03	B.	+30 31	N.E.	−78 41	−3 47	+52	+27 36	+29 24	Very unsteady.
16 P.M.	−54 42	106 08	Cl.	+32 16	N.E. ½ E.		−3 56	+52	+29 12		
	−54 42	106 08	T.	+32 06	N.E. ½ E.		−3 56	+52	+29 02		
	−54 38	106 28	M.	+33 16	E.		−4 46	+52	+29 22		
	−54 38	106 28	Cl.	+34 13	E.		−4 46	+52	+30 19		
	−54 36	106 28	Bn.	+34 45	E.		−4 46	+52	+30 51		
17 A.M.	−54 05	108 15	Cl.	+29 19	E. by S.	−79 04	−4 52	+52	+25 19	+26 34	Very unsteady.
	−54 05	108 15	M.	+32 02	E. ½ S.		−5 05	+52	+27 49		
18 A.M.	−53 30	110 13	Bn.	+25 18	N.N.E.	−77 34	−2 37	+52	+23 33	+21 52	Very unsteady.
	−53 14	110 24	M.	+22 05	N.N.E. ½ E.		−2 58	+52	+19 59		
	−53 10	110 27	M.	+26 50	N.E. ½ E.		−4 01	+52	+23 41		
	−53 08	110 29	M.	+26 25	N.E.		−3 47	+52	+23 30		
	−53 08	110 29	Cl.	+23 34	N.E. ½ E.		−4 01	+52	+20 25		
18 P.M.	−53 03	110 20	T.	+20 00	N. ½ W.		− 48	+52	+20 04		
19 P.M.	−52 38	110 30	Cl.	+18 23	N.N.E.	−77 09	−2 32	+52	+16 43	+16 43	Very unsteady.
20 A.M.	−49 22	112 34	Bn.	+23 05	N.E. by N.	−76 17	−2 49	+52	+21 08	+17 09	Compass unsteady.
	−49 22	112 34	Bn.	+21 06	N. by E. ½ E.		−2 04	+52	+19 54		
	−49 22	112 34	Bn.	+20 05	N.N.E.		−2 19	+52	+18 38		
	−49 01	112 50	M.	+19 26	N.E.		−3 25	+52	+16 53		
20 P.M.	−49 00	112 51	Cl.	+17 58	N.E. ½ N.		−3 10	+52	+15 40		
	−49 00	112 51	Cl.	+18 30	N.E. ½ N.		−3 10	+52	+16 12		
	−48 59	112 53	T.	+21 50	N.E. ½ E.		−3 35	+52	+19 07		
	−48 54	112 55	T.	+17 12	N.E. ½ E.		−3 35	+52	+14 29		
	−48 56	112 56	M.	+17 24	N.E. ½ E.		−3 35	+52	+14 41		
	−48 56	112 56	M.	+17 33	N.E. ½ E.		−3 35	+52	+14 50		
23 P.M.	−46 32	115 54	M.	+11 55	N. ½ W.	−74 30	− 45	+52	+12 02	+12 02	Steady.
24 P.M.	−45 04	116 52	T.	+ 8 52	N. ½ W.	−73 27	− 45	+52	+ 8 59	+ 9 43	Very unsteady.
	−44 54	116 55	M.	+10 38	N.		−1 03	+52	+10 27		
25 A.M.	−43 53	116 52	M.	+ 7 12	N. by W. ½ W.	−72 28	− 30	+52	+ 7 34	+ 7 04	Card unsteady.
	−43 52	116 59	B.	+ 5 40	N. by W.		− 42	+52	+ 5 50		
	−43 52	116 59	Bn.	+ 8 18	N. ½ W.		− 54	+52	+ 8 16		
	−43 42	116 59	Cl.	+ 7 42	N.		−1 00	+52	+ 7 34		
	−43 42	116 59	T.	+ 5 59	N.		−1 00	+52	+ 5 51		
25 P.M.	−43 08	116 55	Cl.	+ 7 45	N. ½ E.		−1 12	+52	+ 7 25		
26 A.M.	−41 29	116 42	M.	+ 3 45	N. by W.	−70 43	− 33	+52	+ 4 04	+ 4 10	Card unsteady.
26 P.M.	−40 54	116 42	Cl.	+ 4 48	N. by W.		− 33	+52	+ 5 07		
	−40 42	116 42	M.	+ 3 10	N. by W.		− 33	+52	+ 3 29		
27 A.M.	−39 00	116 15	M.	+ 7 09	N. by W.	−68 27	− 33	+52	+ 7 28	+ 6 56	Compass steady.
	−39 00	116 15	Cl.	+ 6 26	N. by W.		− 33	+52	+ 6 45		
27 P.M.	−38 32	116 17	M.	+ 7 48	N. by E.		−1 20	+52	+ 7 20		
	−38 08	116 19	M.	+ 6 37	N. by E.		−1 20	+52	+ 6 09		
28 P.M.	−37 02	116 38	M.	+ 4 10	N. by E. ½ E.	−66 38	−1 11	+52	+ 3 51	+ 4 31	Steady.
	−36 46	116 35	M.	+ 5 45	N.N.E.		−1 26	+52	+ 5 11		
	−36 46	116 35	Cl.	+ 5 13	N.N.E. ½ E.		−1 33	+52	+ 4 32		
29 A.M.	−36 13	116 40	M.	+ 4 49	N. by E.	−65 44	−1 07	+52	+ 4 34	+ 4 52	Steady.
	−36 12	116 40	M.	+ 5 56	N. by E.		−1 07	+52	+ 5 41		
	−36 13	116 40	Cl.	+ 4 29	N. by E.		−1 07	+52	+ 4 14		
	−36 12	116 40	T.	+ 4 52	N. by E.		−1 07	+52	+ 4 37		
	−36 11	116 40	M.	+ 5 38	N.		− 53	+52	+ 5 37		
29 P.M.	−36 10	116 47	Bn.	+ 4 37	N.E. ½ E.		−1 56	+52	+ 3 33		
	−36 10	116 47	Cl.	+ 6 01	N.E. ½ E.		−1 56	+52	+ 4 57		
	−36 08	116 54	M.	+ 6 48	N.E. ½ E.		−1 56	+52	+ 5 44		
30 A.M.	−35 09	117 41	Cl.	+ 7 10	S.E. ½ E.	−65 36	−1 34	+52	+ 6 28	+ 6 20	Compass steady.
	−35 09	117 41	Cl.	+ 6 54	N. ½ E.		− 59	+52	+ 6 47		
	−35 14	117 41	Cl.	+ 4 52	S. ½ E.		− 13	+52	+ 5 31		
	−35 14	117 41	Bn.	+ 5 05	S. ½ E.		− 13	+52	+ 5 44		
30 P.M.	−35 14	117 41	M.	+ 6 23	S.		− 03	+52	+ 7 12		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845.											
Mar. 31 A.M.	−35° 28′	117° 04′	Cl.	+7° 59′	N.E. ½ E.	−65° 20′	−1° 56′	+52′	+6° 55′	+6° 55′	Unsteady.
April 1 A.M.	−35 08	117 50	Cl.	+9 57	N.N.E.	−65 00	−1 22	+52	+9 27	+9 27	Unsteady.
11 A.M.	−35 02	117 56	M.	+4 17	Observed on shore.			+52	+5 09	+5 33	Card J.
14 A.M.	King George's		Cl.	+4 53				+52	+5 45		Card J.
	Sound, Australia		Cl.	+4 58				+47	+5 45		Card A.
21 A.M.	−35 10	118 06	M.	+3 48	W. by S.	−65 11	+1 17	+52	+5 57	+5 57	Card J. unsteady.
22 A.M.	−35 42	115 40	M.	+5 10	S.	−65 11	− 03	+52	+5 59	+5 59	Unsteady.
23 A.M.	−35 40	114 55	Cl.	+3 05	N.W.	−65 11	+ 21	+52	+4 18	+5 41	Unsteady.
	−35 38	114 50	M.	+4 33	N.N.W. ½ W.		− 09	+52	+5 16		
23 P.M.	−35 23	114 21	M.	+6 29	N.W. ½ N.		+ 09	+52	+7 30		
24 A.M.	−34 24	113 17	M.	+6 31	N.W. by N.	−64 44	− 04	+52	+7 19	+6 37	Card unsteady.
	−34 20	113 15	Cl.	+6 10	N.W. by N.		− 04	+52	+6 58		
	−34 17	113 12	Cl.	+5 34	N.W. by N.		− 04	+52	+6 22		
Noon.	−34 12	113 05	M.	+5 00	N.W. by N.		− 04	+52	+5 48		
25 A.M.	−32 48	111 44	M.	+6 55	N.W. by N.	−62 18	− 08	+52	+7 39	+6 36	Steady.
	−32 48	111 45	Cm.	+6 04	N.W. by N.		− 08	+52	+6 48		
	−32 40	111 44	Cl.	+5 20	N.W. ½ N.		− 06	+52	+6 06		
	−32 38	111 43	Cl.	+5 05	N.W. ½ N.		− 06	+52	+5 51		
	−32 35	111 40	Cl.	+5 53	N.W. by N.		− 08	+52	+6 37		
26 A.M.	−30 31	109 15	Cl.	+5 58	N.W. by N.	−60 30	− 12	+52	+6 38	+7 20	Unsteady.
	−30 31	109 15	Bn.	+6 25	N.W. by N.		− 12	+52	+7 05		
26 P.M.	−30 26	108 58	M.	+5 58	N.W.		+ 02	+52	+6 52		
	−30 15	108 58	Cm.	+7 52	N.W.		+ 02	+52	+8 46		
27 A.M.	−29 20	106 55	M.	+6 04	N.W. ½ W.	−59 25	+ 10	+52	+7 06	+6 30	Steady.
	−29 20	106 55	Cm.	+5 00	N.W.		+ 02	+52	+5 54		
28 A.M.	−27 57	106 36	M.	+8 27	N.	−57 22	− 50	+52	+8 29	+6 33	Very unsteady.
28 P.M.	−27 25	106 34	Cl.	+4 26	N. by W.		− 40	+52	+4 38		
29 A.M.	−26 10	105 16	M.	+3 56	N.W.	−55 07	− 07	+52	+4 41	+5 30	Very unsteady.
	−26 10	105 16	Cl.	+5 52	N.W.		− 07	+52	+6 37		
	−26 10	105 16	Bn.	+5 28	N.W.		− 07	+52	+6 13		
30 A.M.	−24 10	102 30	Cl.	+3 58	W.N W.	−54 30	+ 20	+52	+5 10	+5 32	Very unsteady.
	−24 05	102 26	M.	+4 42	W.N.W.		+ 20	+52	+5 54		
May 1 A.M.	−23 58	99 26	Cl.	+3 02	W.	−54 07	+ 38	+52	+4 32	+5 14	Unsteady.
	−23 58	99 25	Cl.	+3 00	W.		+ 38	+52	+4 30		
	−23 58	99 22	M.	+4 25	W.		+ 38	+52	+5 55		
Noon.	−23 58	99 13	M.	+4 30	W.		+ 38	+52	+6 00		
2 A.M.	−24 01	97 34	M.	+7 57	N. by E. ½ E.	−54 11	− 58	+52	+7 51	+7 08	Compass steady.
	−24 01	97 34	M.	+7 50	N.N.E.		−1 00	+52	+7 42		
	−24 01	97 34	Bn.	+6 26	N. by E. ½ E.		− 58	+52	+6 20		
	−24 01	97 34	Cl.	+6 47	N.N.E.		−1 00	+52	+6 39		
3 A.M.	−23 55	95 58	M.	+5 58	W. ½ N.	−54 21	+ 40	+52	+7 30	+6 10	Steady.
	−23 55	95 58	M.	+4 58	W. ½ N.		+ 40	+52	+6 30		
	−23 55	95 58	Cl.	+3 40	W. ½ N.		+ 40	+52	+5 12		
3 P.M.	−24 00	95 25	M.	+4 41	W. ½ S.		+ 33	+52	+6 06		
	−24 00	95 25	Cl.	+4 05	W. ½ S.		+ 33	+52	+5 30		
	−23 55	95 50	Cm.	+4 42	W. ½ S.		+ 40	+52	+6 14		
4 A.M.	−24 17	94 08	Cl.	+5 09	W.N.W.	−54 07	+ 12	+52	+6 13	+5 31	
	−24 17	94 10	M.	+4 22	W.N.W.		+ 12	+52	+5 26		Card J. steady.
	−24 17	94 10	M.	+3 51	W.N.W.		+ 12	+47	+4 50		Card A. steady.
Noon.	−24 17	93 58	M.	+4 30	W.N.W.		+ 12	+52	+5 34		Card J. steady.
5 A.M.	−24 05	92 11	Cl.	+6 05	N.W. by N.	52 44	− 23	+52	+6 34	+6 34	Steady.
6 A.M.	−22 54	90 50	M.	+4 38	N.W.	−52 49	− 13	+52	+5 17	+5 56	Compass steady.
	−22 54	90 50	Bn.	+4 57	N.W.		− 13	+52	+5 36		
	−22 54	90 50	Cl.	+4 49	N.W.		− 13	+52	+5 28		
	−22 50	90 48	Cl.	+5 04	N.W.		− 13	+52	+5 43		
6 P.M.	−22 39	90 35	M.	+5 59	N.W. by N.		− 23	+52	+6 28		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845. May 6 P.M.	−22° 39′	90° 32′	M.	+6° 12′	N.N.W.	−52° 49′	− ° 34′	+52′	+6° 30′	+5° 56′	Compass steady.
	−22 39	90 32	Bn.	+4 40	N.W. by N.		− 23	+52	+5 09		
	−22 39	90 32	Cl.	+5 53	N.W. by N.		− 23	+52	+6 22		
Sunset.	−22 39	90 32	Cl.	+6 33	N.N.W.		− 34	+52	+6 51		
7 A.M.	−21 53	89 42	M.	+3 30	N.W.	−52 01	− 18	+52	+4 04	+4 23	Unsteady.
	−21 53	89 42	Cl.	+4 09	N.W.		− 18	+52	+4 43		
8 A.M.	−20 48	88 08	M.	+3 42	N.W. by W.	−51 15	− 10	+52	+4 24	+4 45	Card steady.
	−20 47	88 05	M.	+3 53	N.W. by W.		− 10	+52	+4 35		
	−20 45	88 05	Cl.	+3 25	N.W. by W.		− 10	+52	+4 07		
	−20 45	88 05	Bn.	+4 11	N.W. by W.		− 10	+52	+4 53		
Noon.	−20 38	87 56	M.	+4 30	W. ½ N.		+ 26	+52	+5 48		
9 A.M.	−20 37	85 39	M.	+4 38	W. ½ N.	−51 18	+ 26	+52	+5 56	+5 20	Steady.
	−20 37	85 39	Cl.	+3 28	W. ½ N.		+ 26	+52	+4 46		
Noon	−20 37	85 19	M.	+4 00	W. ½ N.		+ 26	+52	+5 18		
10 A.M.	−20 25	82 45	M.	+4 12	W. ½ N.	−51 22	+ 26	+52	+5 30	+5 08	Very unsteady.
	−20 25	82 24	M.	+4 17	W. ½ N.		+ 26	+52	+5 35		
	−20 25	82 30	Bn.	+3 06	W. ½ N.		+ 26	+52	+4 24		
	−20 25	82 30	Cl.	+3 26	W. ½ N.		+ 26	+52	+4 44		
	−20 25	82 30	T.	+4 08	W. ½ N.		+ 26	+52	+5 26		
11 A.M.	−20 36	79 36	M.	+2 56	W. ¼ N.	−51 48	+ 24	+52	+4 12	+4 43	Compass unsteady.
	−20 36	79 34	M.	+2 31	W. ¼ N.		+ 24	+52	+3 47		
	−20 36	79 34	Bn.	+2 27	W. ¼ N.		+ 24	+52	+3 43		
	−20 36	79 34	Cl.	+3 12	W. ¼ N.		+ 24	+52	+4 28		
11 P.M.	−20 36	79 00	M.	+4 48	W. ¼ N.		+ 24	+52	+6 04		
	−20 36	79 00	Cl.	+4 34	W. ¼ N.		+ 24	+52	+5 50		
	−20 36	79 00	T.	+3 43	W. ¼ N.		+ 24	+52	+4 59		
12 A.M.	−20 44	78 34	M.	+5 38	N.	−52 02	− 50	+52	+5 40	+5 29	To obtain corrections for the ship's attraction. A calm, heavy swell, compass unsteady.
	−20 44	78 34	Cl.	+6 28	N.		− 50	+52	+6 30		
	−20 44	78 34	M.	+5 06	N.N.W.		− 38	+52	+5 20		
	−20 44	78 34	Cl.	+6 32	N.N.W.		− 38	+52	+6 46		
	−20 44	78 34	M.	+5 27	N.W.		− 22	+52	+5 57		
	−20 44	78 34	Cl.	+5 12	N.W.		− 22	+52	+5 42		
	−20 44	78 34	M.	+3 23	W.N.W.		+ 04	+52	+4 19		
	−20 44	78 34	Cl.	+5 36	W.N.W.		+ 04	+52	+6 32		
	−20 44	78 34	M.	+2 23	W.		+ 20	+52	+3 35		
	−20 44	78 34	Cl.	+4 09	W.		+ 20	+52	+5 21		
	−20 44	78 34	M.	+2 58	W.S.W.		+ 15	+52	+4 05		
	−20 44	78 34	Cl.	+4 22	W.S.W.		+ 15	+52	+5 29		
	−20 44	78 34	M.	+4 20	S.W.		+ 06	+52	+5 18		
	−20 44	78 34	Cl.	+4 26	S.W.		+ 06	+52	+5 24		
	−20 44	78 34	M.	+4 46	S.S.W.		− 01	+52	+5 37		
	−20 44	78 34	Cl.	+4 48	S.S.W.		− 01	+52	+5 39		
	−20 44	78 34	M.	+4 42	S.		− 08	+52	+5 26		
	−20 44	78 34	Cl.	+4 29	S.		− 08	+52	+5 13		
	−20 44	78 34	M.	+5 41	E.N.E.		−1 13	+52	+5 20		
	−20 44	78 34	Cl.	+6 00	E.N.E.		−1 13	+52	+5 39		
	−20 44	78 34	M.	+6 21	N.N.E.		− 57	+52	+6 16		
13 A.M.	−20 39	77 45	Cl.	+4 11	W.	−51 59	+ 20	+52	+5 23	+5 22	Steady.
	−20 39	77 45	T.	+4 29	W.		+ 20	+52	+5 41		
	−20 39	77 45	M.	+3 49	W.		+ 20	+52	+5 01		
14 A.M.	−20 28	76 23	M.	+4 43	W. ½ N.	−52 20	+ 16	+52	+5 51	+6 01	Very unsteady.
	−20 28	76 23	Bn.	+4 25	W. ½ N.		+ 16	+52	+5 33		
	−20 28	76 23	Cl.	+5 31	W. ½ N.		+ 16	+52	+6 39		
15 A.M.	−20 45	73 20	M.	+4 46	W. ½ N.	−52 25	+ 16	+52	+5 54	+5 54	Unsteady.
16 A.M.	−20 27	70 49	M.	+6 12	W. ½ N.	−52 35	+ 16	+52	+7 20	+6 35	Card unsteady.
	−20 27	70 49	Cl.	+4 43	W. ½ N.		+ 16	+52	+5 51		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		° ′	′	′	° ′	° ′	
May 17 A.M.	−20 34	69 40	Cl.	+ 5 06	w.	−53 01	+20	+52	+ 6 18	+ 6 07	Card unsteady.
	−20 34	69 35	Cl.	+ 4 45	w.		+20	+52	+ 5 57		
18 A.M.	−21 06	68 30	Cl.	+ 6 28	w. ¼ s.	−53 06	+20	+52	+ 7 40	+ 8 00	Compass steady.
	−21 00	68 22	M.	+ 6 24	w. by s.		+18	+52	+ 7 34		
P.M.	−20 52	68 04	M.	+ 7 35	N.N.W.		−37	+52	+ 7 50		
	−20 52	68 04	Bn.	+ 8 59	N.N.W.		−37	+52	+ 9 14		
Sunset.	−21 00	68 00	M.	+ 7 45	N. by w. ½ w.		−47	+52	+ 7 40		
19 A.M.	−21 11	67 54	M.	+ 6 40	N.W.	−53 24	−19	+52	+ 7 13	+ 6 34	Card steady.
	−21 11	67 54	Cl.	+ 6 21	N.W. ½ N.		−23	+52	+ 6 50		
	−21 11	67 54	T.	+ 5 11	N.W. ½ N.		−23	+52	+ 5 40		
20 A.M.	−21 12	67 29	Cl.	+ 6 24	w. by N.	−53 49	+15	+52	+ 7 31	+ 7 37	Steady.
	−21 12	67 29	Bn.	+ 6 36	w. by N.		+15	+52	+ 7 43		
21st A.M.	−21 01	66 26	Cl.	+ 6 53	w. by N.	−53 56	+15	+52	+ 8 00	+ 7 46	
	−21 01	66 26	Bn.	+ 6 34	w. by N.		+15	+52	+ 7 41		
	−21 01	66 20	M.	+ 6 30	w. by N.		+15	+52	+ 7 37		
22 A.M.	−20 41	63 16	M.	+ 7 17	w. by N.	−53 53	+15	+52	+ 8 24	+ 8 27	
Sunset.	−20 38	62 44	M.	+ 7 23	w. by N.		+15	+52	+ 8 30		
23 A.M.	−20 30	59 42	Cl.	+ 8 40	w. by N.	−54 09	+15	+52	+ 9 47	+ 9 44	
	−20 30	59 42	Bn.	+ 8 12	w. by N.		+15	+52	+ 9 19		
	−20 30	59 42	M.	+ 9 00	w. by N.		+15	+52	+10 07		
24 A.M.	−19 54	57 55	M.	+ 8 15	w. ½ N.	−53 56	+20	+52	+ 9 27	+ 9 27	Very unsteady.
27 A.M.	−20 09	57 31	M.	+ 8 31	On shore.			+52	+ 9 23	+ 9 44	Port Louis, Mauritius.
	−20 09	57 31	M.	+ 9 13				+52	+10 05		
29 A.M.	−20 50	55 31	Cl.	+ 9 13	w.	−54 00	+26	+52	+10 31	+11 15	Card steady.
	−20 50	55 33	M.	+10 47	w. ½ N.		+20	+52	+11 59		
30 A.M.	−21 30	53 10	M.	+12 09	s.w.byw.½w.	−54 45	+19	+52	+13 20	+13 44	
P.M.	−22 02	52 58	Cl.	+12 44	s.w. by w.		+16	+52	+13 52		
	−22 02	52 58	B.	+12 34	s.w. by w.		+16	+52	+13 42		
	−22 02	52 58	M.	+12 54	s.w. by w.		+16	+52	+14 02		
31 P.M.	−23 44	51 48	Cl.	+12 17	s.w.byw.½w.	−56 02	+19	+52	+13 28	+14 22	Card unsteady.
	−23 44	51 48	Cl.	+13 48	s.w.byw.½w.		+19	+52	+14 59		
	−23 44	51 48	M.	+13 28	s.w.byw.½w.		+19	+52	+14 39		
June 1 A.M.	−25 47	49 40	Cl.	+14 16	w.s.w.	−57 19	+27	+52	+15 35	+15 09	Unsteady.
	−25 47	49 40	M.	+13 24	w.s.w.		+27	+52	+14 43		
2 A.M.	−26 30	49 20	M.	+15 38	N.W.	−58 36	−01	+52	+16 29	+16 23	
	−26 30	49 20	Cl.	+15 25	N.W.		−01	+52	+16 16		
	−26 30	49 20	T.	+15 32	N.W.		−01	+52	+16 23		
4 A.M.	−27 10	46 09	Cl.	+19 50	w. by s.	−58 38	+48	+52	+21 30	+20 25	Very unsteady.
	−27 10	46 09	Cl.	+19 01	w. by s.		+48	+52	+20 41		
	−27 07	46 14	M.	+17 56	w. by s.		+48	+52	+19 36		
4 P.M.	−27 14	45 59	M.	+19 18	w. by s.		+48	+52	+20 58		
Sunset.	−27 18	45 39	Cl.	+17 38	w.		+51	+52	+19 21		
5 A.M.	−28 19	43 11	Cl.	+19 40	w.	−58 31	+31	+52	+21 03	+21 19	Card very unsteady.
	−28 19	43 11	M.	+21 14	w.		+31	+52	+22 37		
	−28 20	43 00	Cl.	+18 55	w.		+31	+52	+20 18		
6 A.M.	−28 50	42 07	M.	+19 58	N.W. by w.	−59 01	+12	+52	+21 02	+21 57	Very unsteady.
	−28 49	42 10	M.	+19 47	N.W. by w.		+12	+52	+20 51		
	−28 49	42 11	Cl.	+21 48	N.W. by w.		+12	+52	+22 52		
	−28 46	42 00	M.	+22 00	N.W. by w.		+12	+52	+23 04		
7 A.M.	−28 32	40 32	M.	+21 48	w. by N.	−58 54	+22	+52	+23 02	+22 34	Unsteady.
	−28 38	40 20	M.	+21 29	w. by N.		+22	+52	+22 43		
	−28 32	40 32	Cl.	+21 04	w. by N.		+22	+52	+22 18		
7 P.M.	−28 40	39 52	M.	+21 17	w. by N.		+22	+52	+22 31		
	−28 40	39 52	Cl.	+21 04	w. by N.		+22	+52	+22 18		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		° ′	° ′	′	° ′	° ′	
June 8 A.M.	−28 50	37 58	M.	+21 41	W.	−59 11	+ 32	+52	+23 05	+23 37	
	−28 53	37 55	M.	+22 17	W.		+ 32	+52	+23 41		
	−28 56	37 56	Cl.	+21 49	W. ½ S.		+ 31	+52	+23 12		
	−28 56	37 56	T.	+22 00	W. ½ S.		+ 27	+52	+23 19		
	−28 58	37 49	M.	+21 44	W.		+ 32	+52	+23 08		
8 P.M.	−29 03	37 37	M.	+23 19	W. ½ S.		+ 31	+52	+24 42		
Sunset.	−29 03	37 37	Cl.	+22 48	W. ½ S.		+ 31	+52	+24 11		
9 A.M.	−30 20	36 04	M.	+25 36	W. ½ S.	−57 59	+ 30	+52	+26 58	+26 29	Very unsteady.
	−30 16	35 46	Cl.	+24 38	W. ½ S.		+ 30	+52	+26 00		
11 A.M.	−30 30	33 45	M.	+26 28	N.W. by W.	−56 37	− 07	+52	+27 13	+27 28	Very unsteady.
11 P.M.	−30 27	33 41	Cl.	+24 42	W. ½ N.		+ 24	+52	+25 58		
	−30 30	33 41	M.	+27 05	S.E.		− 40	+52	+27 17		
	−30 30	33 41	M.	+26 59	N.E.		−1 10	+52	+26 41		
	−30 30	33 41	Bn.	+27 43	S.E.		− 40	+52	+27 55		
	−30 30	33 41	Cl.	+29 36	S.E. ½ E.		− 46	+52	+29 42		
12 A.M.	−30 35	33 13	M.	+23 58	W. by N.	−57 19	+ 19	+52	+25 09	+25 09	Very unsteady.
13 A.M.	−31 05	31 39	M.	+25 15	W. by S. ½ S.	−57 26	+ 25	+52	+26 32	+26 46	Card steady.
	−31 05	31 34	M.	+25 22	W. by S. ½ S.		+ 25	+52	+26 39		
	−31 06	31 30	M.	+25 13	W. by S. ½ S.		+ 25	+52	+26 30		
	−31 10	31 28	M.	+25 25	W. by S. ½ S.		+ 25	+52	+26 42		
	−31 05	31 39	Bn.	+27 16	W. by S.		+ 26	+52	+28 34		
	−31 05	31 34	Cl.	+25 46	W. by S. ½ S.		+ 25	+52	+27 03		
13 P.M.	−31 12	31 28	Cl.	+24 39	S.W. by W. ½ W.		+ 21	+52	+25 52		
	−31 18	31 23	M.	+25 06	S.W. by W. ½ W.		+ 21	+52	+26 19		
	−31 18	31 23	Cl.	+25 26	S.W. by W. ½ W.		+ 21	+52	+26 39		
14 A.M.	−32 50	29 51	M.	+28 06	S.W. by W. ½ W.	−57 34	+ 22	+52	+29 20	+28 44	Card unsteady.
	−32 53	29 45	Cl.	+27 02	W. ½ S.		+ 30	+52	+28 24		
	−32 53	29 45	T.	+27 19	W. ½ S.		+ 30	+52	+28 41		
	−33 00	29 55	Cl.	+27 09	W.		+ 31	+52	+28 32		
15 A.M.	−34 36	27 14	M.	+27 06	W. ½ S.	−57 06	+ 30	+52	+28 28	+28 41	
	−34 36	27 12	T.	+26 23	W. ½ S.		+ 30	+52	+27 45		
	−34 45	27 02	M.	+26 08	W. ½ N.		+ 26	+52	+27 26		
	−34 40	27 10	Cl.	+27 58	W. ½ N.		+ 26	+52	+29 16		
	−34 40	27 10	Bn.	+28 21	W. ½ N.		+ 26	+52	+29 39		
	−34 45	27 00	Cl.	+26 52	W. ½ N.		+ 26	+52	+28 10		
15 Noon.	−34 51	26 46	Cl.	+28 50	N.W. by W. ½ W.		+ 02	+52	+29 44		
P.M.	−34 51	25 58	M.	+27 54	N.W. by W.		00	+52	+28 46		
	−34 51	25 58	Cl.	+27 54	N.W. by W.		00	+52	+28 46		
16 A.M.	−35 36	23 38	M.	+27 11	W. ½ S.	−56 08	+ 27	+52	+28 30	+29 26	Card unsteady.
	−35 36	23 38	Bn.	+27 26	W. ½ S.		+ 27	+52	+28 45		
	−35 40	23 34	Cl.	+28 06	W. by N.		+ 17	+52	+29 15		
	−35 42	23 32	Cl.	+28 14	W. by N.		+ 17	+52	+29 23		
	−35 43	23 31	Cl.	+31 16	N. ½ E.		− 53	+52	+31 15		
17 A.M.	−35 40	21 41	Cl.	+28 38	N.W. ½ W.	−55 25	− 14	+52	+29 16	+29 16	
	−35 40	21 34	M.	+28 21	W.N.W.		+ 04	+52	+29 17		
18 A.M.	−35 06	20 46	M.	+26 41	W. by S.	−55 08	+ 23	+52	+27 56	+27 56	
19 A.M.	−35 08	20 24	Cl.	+27 29	S.W. ¾ S.	−54 50	+ 19	+52	+28 40	+28 47	
	−35 08	20 24	M.	+27 43	S.W. ¾ S.		+ 19	+52	+28 54		
20 A.M.	−34 55	19 35	Cl.	+29 00	N.W.	−54 00	− 19	+52	+29 33	+28 57	
	−34 55	19 35	Cl.	+28 14	N.W. by W. ½ W.		00	+52	+29 06		
	−34 55	19 30	Cl.	+27 34	N.W. ½ W.		− 14	+52	+28 12		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Corrections.		Corrected Declination.		Remarks.
							Ship's attraction.	Index.			
1845. June 23.	−34° 12′	18° 27′	M.	+29° 11′	N.	−53° 37′	− ° 50′	+52′	+29° 13′	+29° 15′	To obtain the corrections for the ship's iron.
	At anchor in Simon's Bay.	Cape of Good Hope.	M.	+28 52	N.N.W.		− 37	+52	+29 07		
			M.	+28 23	N.W.		− 19	+52	+28 56		
			M.	+28 23	W.N.W.		+ 04	+52	+29 19		
			M.	+27 40	W.		+ 26	+52	+28 58		
			M.	+27 28	W.S.W.		+ 21	+52	+28 41		
			M.	+27 14	S.W.		+ 11	+52	+28 17		
			M.	+27 40	S.S.W.		+ 02	+52	+28 34		
			M.	+28 36	S.		− 07	+52	+29 21		
			M.	+29 30	S.S.E.		− 20	+52	+30 02		
			M.	+29 34	S.E.		− 39	+52	+29 47		
			M.	+29 47	E.S.E.		−1 01	+52	+29 38		
			M.	+30 22	E.		−1 23	+52	+29 51		
			M.	+29 56	E.N.E.		−1 19	+52	+29 29		
			M.	+29 51	N.E.		−1 09	+52	+29 34		
			M.	+29 26	N.N.E.		−1 00	+52	+29 18		
July 1.	−33 56	18 29	Cl.	+28 26	To obtain the Index Corrections for Cards A and J; true Declination = +29 07.			+52	+29 18	+29 07	Card J. error −52′. Card A. error −47′.
	Magnetic Observatory, Cape of Good Hope.		Cl.	+28 11				+52	+29 03		
11.			Cl.	+28 07				+52	+28 59		
			Cl.	+28 20				+47	+29 07		

Observations of the INCLINATION made on board Her Majesty's hired Bark "Pagoda," from the 10th of January to the 21st of July 1845, with Needle A (Fox C. 9). Face East.

Observer Lieut. T. E. L. MOORE, R.N. One hour after Noon.

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1845.	° ′	° ′		° ′		′	′	° ′	
Jan. 10.	−34 46	17 46	Direct.	−54 26	W. by N.	+63	−26	−53 34	Fresh breeze, a hea swell.
			Needle N.	−54 44	W. by N.				
			Needle S.	−53 27	W. by N.				
			Mag. N.	−54 22	W. by N.				
			Mag. N.S.	−53 53	W. by N.				
			Mag. S.	−53 54	W. by N.				
			Direct.	−54 32	W. by N.				
11.	−35 29	15 09	Direct.	−52 27	N.W. by W.	+80	−26	−51 27	A little motion.
			Needle N.	−52 38	N.W. by W.				
			Needle S.	−51 42	N.W. by W.				
			Mag. N.S.	−52 55	N.W. by W.				
			Mag. N.	−52 15	N.W. by W.				
			Mag. S.	−52 09	N.W. by W.				
12.	−35 17	14 00	Direct.	−51 45	W. ½ S.	+50	−26	−51 16	A little motion.
			Needle N.	−52 17	W. ½ S.				
			Needle S.	−51 20	W. ½ S.				
			Mag. N.S.	−51 56	W. ½ S.				
			Mag. N.	−51 29	W. ½ S.				
			Mag. S.	−51 26	W. ½ S.				
			Direct.	−51 31	W. ½ S.				
13.	−35 24	13 23	Direct.	−51 38	S.W. ½ S.	+27	−26	−51 19	A little motion.
			Needle N.	−51 31	S.W. ½ S.				
			Needle S.	−50 41	S.W. ½ S.				
			Mag. N.S.	−51 42	S.W. ½ S.				
			Mag. N.	−51 18	S.W. ½ S.				
			Mag. S.	−51 10	S.W. ½ S.				
15.	−38 42	14 27	Direct.	−53 30	S. by W. ½ W.	+18	−26	−53 31	A head swell, tab unsteady.
			Needle N.	−53 47	S. by W. ½ W.				
			Needle S.	−52 36	S. by W. ½ W.				
			Mag. N.S.	−53 38	S. by W. ½ W.				
			Mag. N.	−53 19	S. by W. ½ W.				
			Mag. S.	−53 22	S. by W. ½ W.				
			Direct.	−53 33	S. by W. ½ W.				
16.	−39 10	14 38	Direct.	−54 03	S.W. by W. ½ W.	+12	−26	−54 12	Table very unstead
			Needle N.	−54 24	S.W. by W. ½ W.				
			Needle S.	−53 30	S.W. by W. ½ W.				
			Mag. N.S.	−54 07	S.W. by W. ½ W.				
			Mag. N.	−54 05	S.W. by W. ½ W.				
			Mag. S.	−53 58	S.W. by W. ½ W.				
			Direct.	−53 36	S.W. by W. ½ W.				
17.	−40 41	14 16	Direct.	−55 17	W.S.W.	+40	−26	−54 59	A heavy head swe much motion.
			Needle N.	−55 27	W.S.W.				
			Needle S.	−54 47	W.S.W.				
			Mag. N.S.	−55 22	W.S.W.				
21.	−50 21	10 31	Direct.	−55 39	S.W.	+24	−26	−55 34	Moderate breezes, little motion.
			Needle N.	−55 32	S.W.				
			Needle S.	−55 15	S.W.				
			Mag. N.S.	−55 49	S.W.				
			Mag. N.	−55 25	S.W.				
			Mag. S.	−55 31	S.W.				

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1845.	° ′	° ′		° ′		′		° ′	
an. 23.	−50 48	10 18	Direct.	−57 23	s.w.byw.½w.	+34	−26	−57 19	A little motion.
			Needle N.	−57 45	s.w.byw.½w.				
			Needle S.	−57 07	s.w.byw.½w.				
			Mag. N.S.	−57 45	s.w.byw.½w.				
			Mag. N.	−57 28	s.w.byw.½w.				
			Mag. S.	−57 19	s.w.byw.½w.				
			Direct.	−57 25	s.w.byw.½w.				
24.	−51 44	9 36	Direct.	−57 24	s.w. by w.	+30	−26	−57 28	Moderate breeze, table steady.
			Needle N.	−57 42	s.w. by w.				
24.	−51 56	9 30	Direct.	−57 41	s.w.byw.½w.	+28	−26	−57 42	A head swell, much motion 4½ P.M.
			Mag. N.S.	−57 46	s.w.byw.½w.				
			Direct.	−57 44	s.w.byw.½w.				
25.	−53 21	7 32	Direct.	−57 26	s.w.byw.½w.	+28	−26	−57 24	Ship passing through streams of loose ice.
			Needle N.	−57 51	s.w.byw.½w.				
			Needle S.	−57 01	s.w. byw.½w.				
			Mag. N.S.	−57 24	s.w.byw.½w.				
			Mag. N.	−57 33	s.w.byw.½w.				
			Mag. S.	−57 21	s.w.byw.½w.				
			Direct.	−57 24	s.w.byw.½w.				
26.	−54 02	6 02	Direct.	−57 56	w. by N.	+61	−26	−56 58	Table steady, small pieces of loose ice about the ship.
			Needle N.	−57 49	w. by N.				
			Needle S.	−57 02	w. by N.				
			Mag. N.S.	−57 55	w. by N.				
			Mag. N.	−57 05	w. by N.				
			Mag. S.	−57 18	w. by N.				
			Direct.	−57 43	w. by N.				
27.	−55 18	5 55	Direct.	−57 30	s.s.w. ½ w.	+10	−26	−58 12	Ship pitching heavily, fresh breezes.
			Needle N.	−58 23	s.s.w. ½ w.				
			Direct.	−57 54	s.s.w. ½ w.				
31.	−61 14	9 07	Direct.	−61 13	s.s.E.	+05	−26	−61 43	Table steady, heavy snow.
			Needle N.	−61 41	s.s.E.				
			Needle S.	−60 41	s.s.E.				
			Mag. N.S.	−61 04	s.s.E.				
			Mag. N.	−60 58	s.s.E.				
			Mag. S.	−61 26	s.s.E.				
			Direct.	−61 23	s.s.E.				
Feb. 1.	−62 06	12 52	Direct.	−62 56	s.E. by s.	0	−26	−63 17	Much motion, table very unsteady, heavy snow.
			Needle N.	−62 41	s.E. by s.				
			Needle S.	−62 36	s.E. by s.				
			Direct.	−63 12	s.E. by s.				
2.	−61 56	16 36	Direct.	−63 59	s.E. ½ E.	+13	−26	−63 55	Heavy snow, a head sea, ship pitching violently, water clear from ice.
			Needle N.	−62 25	s.E. ½ E.				
			Needle S.	−63 37	s.E. ½ E.				
			Needle N.S.	−63 53	s.E. ½ E.				
			Mag. N.	−64 02	s.E. ½ E.				
			Mag. S.	−63 51	s.E. ½ E.				
			Direct.	−64 09	s.E. ½ E.				
3.	−61 50	19 14	Direct.	−65 09	w.s.w.	+25	−26	−64 44	Calm.
			Direct.	−64 49	N.w.	+92			
			Direct.	−65 00	w.	+47			
			Direct.	−64 59	w.s.w.	+25			
			Direct.	−64 44	s.w.	+03			
4.	−63 00	20 40	Direct.	−64 13	s.w.	+03	−26	−64 25	Unsteady.
			Needle N.	−64 12	s.w.				
			Needle S.	−63 39	s.w.				
			Needle N.S.	−64 06	s.w.				
			Mag. N.	−63 59	s.w.				
			Mag. S.	−64 06	s.w.				

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
	° ′	° ′		° ′		′	′	° ′	
1845. Feb. 5.	−63 19	21 48	Direct.	−65 17	S.S.E.	−15	−26	−65 35	Heavy swell from S.E., light breez table steady.
			Needle N.	−64 39	S.S.E.				
			Needle S.	−64 29	S.S.E.				
			Needle N.S.	−64 39	S.S.E.				
			Mag. N.	−64 46	S.S.E.				
			Mag. S.	−64 52	S.S.E.				
			Direct.	−65 25	S.S.E.				
6.	−64 25	24 18	Direct.	−66 17	S.S.E. ½ E.	−14	−26	−66 41	Table steady.
			Needle N.	−66 16	S.S.E. ½ E.				
			Needle S.	−65 28	S.S.E. ½ E.				
			Needle N.S.	−65 58	S.S.E. ½ E.				
			Direct.	−66 07	S.S.E. ½ E.				
7.	−65 39	28 48	Direct.	−67 14	S. by E. ½ E.	−22	−26	−67 56	Table steady.
			Needle N.	−67 19	S. by E. ½ E.				
			Needle S.	−66 54	S. by E. ½ E.				
			Needle N.S.	−67 05	S. by E. ½ E.				
			Mag. N.	−67 02	S. by E. ½ E.				
			Mag. S.	−67 10	S. by E. ½ E.				
8.	−66 27	30 45	Direct.	−68 28	S.E. by E.	+05	−26	−68 31	Fresh breeze, tab steady.
			Needle N.	−68 09	S.E. by E.				
			Needle S.	−67 49	S.E. by E.				
			Needle N.S.	−68 04	S.E. by E.				
			Mag. N.	−68 08	S.E. by E.				
			Mag. S.	−68 06	S.E. by E.				
			Direct.	−68 26	S.E. by E.				
9.	−66 36	36 50	Direct.	−69 11	S.E. by E.	+05	−26	−69 22	Light breeze, ver steady.
			Needle N.	−69 13	S.E. by E.				
			Needle S.	−68 40	S.E. by E.				
			Needle N.S.	−68 47	S.E. by E.				
			Mag. N.	−68 59	S.E. by E.				
			Mag. S.	−69 02	S.E. by E.				
			Direct.	−69 20	S.E. by E.				
10.	−67 10	38 51	Direct.	−70 12	S. by W.	−32	−26	−71 07	Steady.
			Needle N.	−70 53	S. by W.				
			Needle S.	−70 02	S. by W.				
			Needle N.S.	−69 41	S. by W.				
			Mag. N.	−70 00	S. by W.				
			Mag. S.	−70 12	S. by W.				
			Direct.	−70 05	S. by W.				
11.	−67 39	40 28	Direct.	−70 33	N.E.	+89	−26	−69 27	Strong breeze, s ing along a pa of ice, unstea
			Needle N.	−70 26	N.E.				
12.	−67 18	40 22	Direct.	−69 36	S. ½ E.	−32	−26	−70 20	Fresh breeze, ta unsteady.
			Needle N.	−69 43	S. ½ E.				
			Needle S.	−68 58	S. ½ E.				
			Needle N.S.	−69 28	S. ½ E.				
			Mag. N.	−69 18	S. ½ E.				
			Mag. S.	−69 03	S. ½ E.				
			Direct.	−69 28	S. ½ E.				
13.	−66 55	40 16	Direct.	−70 12	E.N.E.	+67	−26	−69 30	A swell from th eastward, tab unsteady.
			Needle N.	−70 28	E.N.E.				
			Needle S.	−69 54	E.N.E.				
			Needle N.S.	−70 08	E.N.E.				
			Mag. N.	−70 14	E.N.E.				
			Mag. S.	−70 06	E.N.E.				
			Direct.	−70 13	E.N.E.				

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed. Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.										
eb. 14.	−66° 24′	40° 01′	Direct.	−70° 38′	N.E. by N.	+89′	−26′	−69° 15′		Very squally, with thick weather, table unsteady.
			Needle N.	−70 07	N.E. by N.					
			Needle S.	−70 10	N.E. by N.					
			Direct.	−70 17	N.E. by N.					
16.	−64 52	38 37	Direct.	−68 03	S. by E.	−30	−26	−68 53		A heavy swell, unsteady.
			Needle N.	−68 13	S. by E.					
			Needle S.	−67 20	S. by E.					
			Needle N.S.	−68 10	S. by E.					
			Mag. N.	−67 52	S. by E.					
			Mag. S.	−68 06	S. by E.					
17.	−64 43	40 12	Direct.	−69 58	N.	+76	−26	−68 18		Calm, a heavy sea, not steady.
			Needle N.	−70 02	N.					
			Needle S.	−69 22	N.					
			Needle N.S.	−68 50	N.					
			Mag. N.	−68 25	N.					
			Mag. S.	−68 30	N.					
			Direct.	−68 50	N.					
19.	−64 05	41 09	Direct.	−70 13	E. by S.	+27	−26	−70 02		Observed the inner circle to have moved, table very unsteady.
			Needle N.	−69 52	E. by S.					
20.	−63 19	45 52	Direct.	−70 29	S.E. by E. ½ E.	+10	−26	−70 14	−70° 15′	A heavy swell.
			Needle N.	−69 51	S.E. by E. ½ E.					
			Needle S.	−69 39	S.E. by E. ½ E.					
			Needle N.S.	−69 54	S.E. by E. ½ E.					
	−63 22	45 58	Direct.	−69 54	S.E.	−08	−26	−70 15		Strong breezes, with a heavy sea running.
			Needle N.	−69 53	S.E.					
			Needle S.	−69 06	S.E.					
			Needle N.S.	−69 50	S.E.					
21.	−63 36	46 46	Direct.	−69 38	S.E.	−08	−26	−70 05	−70 13	Table unsteady, eight icebergs in sight.
			Needle N.	−69 39	S.E.					
			Needle S.	−69 03	S.E.					
			Needle N.S.	−69 43	S.E.					
	−63 36	46 50	Direct.	−70 01	S.E.	−10	−26	−70 21		Much motion.
			Needle N.	−70 02	S.E.					
			Needle S.	−69 34	S.E.					
			Needle N.S.	−69 32	S.E.					
			Mag. N.	−69 37	S.E.					
			Mag. S.	−69 32	S.E.					
			Direct.	−70 00	S.E.					
25.	−61 34	53 49	Direct.	−70 44	S.E. ½ E.	−05	−26	−70 49		Iceblink to the southward, fresh breezes, table unsteady.
			Needle N.	−70 22	S.E. ½ E.					
			Needle S.	−69 58	S.E. ½ E.					
			Needle N.S.	−70 08	S.E. ½ E.					
			Mag. N.	−70 08	S.E. ½ E.					
			Mag. S.	−70 08	S.E. ½ E.					
			Direct.	−70 42	S.E. ½ E.					
26.	−61 19	57 33	Direct.	−71 03	S.E. ½ E.	−07	−26	−71 26		No ice in sight, unsteady.
			Needle N.	−71 24	S.E. ½ E.					
			Needle S.	−70 26	S.E. ½ E.					
			Needle N.S.	−70 40	S.E. ½ E.					
	−61 22	57 41	Direct.	−71 01	S.E.	−13	−26	−71 27		Fresh breeze, table steady.
			Needle N.	−71 22	S.E.					
			Needle S.	−70 30	S.E.					
			Needle N.S.	−70 43	S.E.					
			Mag. N.	−70 29	S.E.					
			Mag. S.	−70 40	S.E.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
Feb. 27.	−61 10	64 20	Direct.	−71 20	S.S.E. ½ E.	−26	−26	−72 18		Very unsteady.
			Needle N.	−71 48	S.S.E. ½ E.					
			Needle S.	−71 10	S.S.E. ½ E.					
28.	−61 49	71 30	Direct.	−72 44	S.S.E.	−33	−26	−73 36	−73 38	Table steady.
			Needle N.	−72 49	S.S.E.					
			Needle S.	−72 36	S.S.E.					
			Needle N.S.	−72 43	S.S.E.					
			Mag. N.	−72 34	S.S.E.					
			Mag. S.	−72 18	S.S.E.					
	−61 49	71 30	Direct.	−72 45	S.S.E.	−36	−26	−73 40		Steady.
			Needle N.	−73 01	S.S.E.					
			Needle S.	−72 12	S.S.E.					
			Needle N.S.	−72 35	S.S.E.					
Mar. 1.	−62 10	72 25	Direct.	−73 37	S.E. by S.	−26	−26	−74 33		Calm, table steady.
			Needle N.	−73 54	S.E. by S.					
			Needle S.	−73 25	S.E. by S.					
			Needle N.S.	−73 42	S.E. by S.					
			Mag. N.	−73 39	S.E. by S.					
			Mag. S.	−73 45	S.E. by S.					
2.	−62 47	76 14	Direct.	−73 41	S. by E. ½ E.	−40	−26	−74 55	−75 05	Steady breeze, table steady.
			Needle N.	−74 12	S. by E. ½ E.					
			Needle S.	−73 39	S. by E. ½ E.					
			Needle N.S.	−73 45	S. by E. ½ E.					
			Mag. N.	−73 48	S. by E. ½ E.					
			Mag. S.	−73 48	S. by E. ½ E.					
	−62 49	76 16	Direct.	−74 11	S.	−45	−26	−75 15		
			Needle N.	−74 21	S.					
			Needle S.	−73 43	S.					
			Needle N.S.	−73 58	S.					
			Direct.	−74 10	S.					
3.	−64 20	79 38	Direct.	−75 02	S. by W. ½ W.	−40	−26	−75 57		Squalls of snow, fresh breeze, unsteady.
			Needle N.	−74 56	S. by W. ½ W.					
			Needle S.	−74 39	S. by W. ½ W.					
			Needle N.S.	−74 41	S. by W. ½ W.					
			Direct.	−74 56	S. by W. ½ W.					
5.	−61 42	85 07	Direct.	−76 13	S.E. ½ E.	−17	−26	−76 58		Table very unsteady, a strong breeze, aurora visible.
			Needle N.	−76 40	S.E. ½ E.					
			Needle S.	−76 18	S.E. ½ E.					
			Needle N.S.	−75 59	S.E. ½ E.					
			Direct.	−76 06	S.E. ½ E.					
6.	−60 48	88 33	Direct.	−76 21	S.E.	−23	−26	−77 04		Very unsteady.
			Needle N.	−76 41	S.E.					
			Needle S.	−76 06	S.E.					
			Needle N.S.	−75 46	S.E.					
			Mag. N.	−75 56	S.E.					
			Mag. S.	−76 16	S.E.					
			Direct.	−76 26	S.E.					
7.	−61 23	91 15	Direct.	−76 26	S.S.W.	−46	−26	−77 41		Aurora visible.
			Needle N.	−77 02	S.S.W.					
			Needle S.	−76 12	S.S.W.					
			Needle N.S.	−76 28	S.S.W.					
			Mag. N.	−76 13	S.S.W.					
			Mag. S.	−76 35	S.S.W.					
			Direct.	−76 26	S.S.W.					
8.	−61 07	92 10	Direct.	−78 11	E. by S.	+13	−26	−78 24	−77 57	Aurora visible; tabl unsteady; snow.
			Needle N.	−77 39	E.S.E.	00	−26	−77 29		
			Needle S.	−76 55	E.S.E.					
			Needle N.S.	−76 39	E.S.E.					
			Direct.	−76 59	E.S.E.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method. employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1845. Mar. 9.	−60° 30′	92° 34′	Direct.	−77° 12′	E.S.E.	−01′	−26′	−77° 37′ } −77° 33′	
			Needle N.	−77 31	S.E. by E.	−10	−26	−77 28	Very unsteady. aurora visible.
			Needle S.	−76 49	S.E. by E.				
			Needle N.S.	−76 26	S.E. by E.				
			Direct.	−76 41	S.E. by E.				
10.	−60 03	96 03	Direct.	−77 10	S.E. by E.	−10	−26	−77 38	Table unsteady, aurora still visible.
			Needle N.	−77 25	S.E. by E.				
			Needle S.	−76 45	S.E. by E.				
			Direct.	−77 01	S.E. by E.				
11	−59 45	99 50	Direct.	−79 30	E. ½ N.	+32	−26	−79 23	A heavy sea, very unsteady.
			Needle N.	−79 13	E. ½ N.				
			Needle S.	−79 29	E. ½ N.				
			Needle N.S.	−79 08	E. ½ N.				
			Mag. N.	−79 45	E. ½ N.				
			Mag. S.	−79 43	E. ½ N.				
			Direct.	−79 35	E. ½ N.				
13.	−57 46	99 17	Direct.	−78 30	E.N.E.	+56	−26	−77 43	6 A.M. The aurora seen faintly, very unsteady.
			Needle N.	−78 04	E.N.E.				
			Needle S.	−78 00	E.N.E.				
			Direct.	−78 20	E.N.E.				
14.	−56 56	101 36	Direct.	−78 04	E. by S.	+13	−26	−78 11	A.M. Aurora visible, unsteady; squally, with snow.
			Needle N.	−78 21	E. by S.				
			Needle S.	−77 33	E. by S.				
			Needle N.S.	−77 54	E. by S.				
			Direct.	−77 58	E. by S.				
15.	−55 40	103 18	Direct.	−78 30	E.N.E.	+56	−26	−78 09	Unsteady.
			Needle N.	−78 53	E.N.E.				
			Needle S.	−78 31	E.N.E.				
			Needle N.S.	−78 53	E.N.E.				
			Direct.	−78 30	E.N.E.				
16.	−54 38	106 15	Direct.	−79 32	E.	+25	−26	−79 13	Heavy squalls, unsteady.
			Needle N.	−79 29	E.				
			Needle S.	−78 48	E.				
			Needle N.S.	−78 55	E.				
			Direct.	−79 13	E.				
17.	−54 10	108 15	Direct.	−79 17	E. by S.	+13	−26	−79 19	A strong gale, very unsteady.
			Needle N.	−79 31	E. by S.				
			Needle S.	−78 38	E. by S.				
			Needle N.S.	−78 56	E. by S.				
			Direct.	−79 10	E. by S.				
18.	−53 00	110 35	Direct.	−78 38	N.E.	+80	−26	−77 39	Unsteady, a heavy swell from the westward, strong breeze.
			Needle N.	−78 51	N.E.				
			Needle S.	−78 39	N.E.				
			Needle N.S.	−78 50	N.E.				
			Mag. N.	−78 25	N.E.				
			Mag. S.	−78 04	N.E.				
			Direct.	−78 26	N.E.				
19.	−51 00	111 29	Direct.	−78 30	N.E.	+80	−26	−77 36	Too unsteady to continue the observation.
20.	−48 57	112 56	Direct.	−77 14	N.E. ½ N.	+84	−26	−76 04	Very unsteady.
			Needle N.	−77 25	N.E. ½ N.				
			Needle S.	−77 01	N.E. ½ N.				
			Needle N.S.	−76 55	N.E. ½ N.				
			Mag. N.	−76 51	N.E. ½ N.				
			Mag. S.	−76 45	N.E. ½ N.				

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1845.	° ′	° ′		° ′		′	′	° ′	
Mar. 22.	−47 21	115 15	Direct.	−76 42	N.W. ½ N.	+85	−26	−75 32	Light breeze, table steady, thick fog.
			Needle N.	−76 31	N.W. ½ N.				
			Needle S.	−76 11	N.W. ½ N.				
			Needle N.S.	−76 28	N.W. ½ N.				
			Mag. N.	−76 38	N.W. ½ N.				
			Mag. S.	−76 29	N.W. ½ N.				
			Direct.	−76 38	N.W. ½ N.				
24.	−45 08	116 50	Direct.	−74 31	N. by E.	+79	−26	−73 27	A heavy sea, ship pitching heavily, very unsteady.
			Needle N.	−74 12	N. by E.				
			Needle S.	−74 02	N. by E.				
			Direct.	−74 37	N. by E.				
25.	−43 22	116 49	Direct.	−73 25	N. ½ E.	+76	−26	−72 10	A heavy westerly swell, unsteady.
			Needle N.	−73 10	N. ½ E.				
			Needle S.	−72 56	N. ½ E.				
			Needle N.S.	−73 18	N. ½ E.				
			Mag. N.	−72 26	N. ½ E.				
			Mag. S.	−72 46	N. ½ E.				
26.	−41 00	116 42	Direct.	−72 09	N. by W.	+80	−26	−71 14	A heavy westerly swell.
			Needle N.	−71 50	N. by W.				
			Needle S.	−71 55	N. by W.				
			Needle N.S.	−72 44	N. by W.				
			Mag. N.	−72 00	N. by W.				
			Mag. S.	−72 12	N. by W.				
			Direct.	−72 09	N. by W.				
27.	−38 40	116 15	Direct.	−69 08	N. by E.	+81	−26	−68 04	Table steady.
			Needle N.	−69 08	N. by E.				
			Needle S.	−68 38	N. by E.				
			Needle N.S.	−68 59	N. by E.				
			Direct.	−69 03	N. by E.				
28.	−37 00	116 57	Direct.	−67 24	N. by E.	+80	−26	−66 21	Table steady, cloudy
			Needle N.	−67 37	N. by E.				
			Needle S.	−66 52	N. by E. ½ E.				
			Needle N.S.	−67 14	N. by E. ½ E.				
			Mag. N.	−67 08	N. by E. ½ E.				
			Mag. S.	−67 18	N. by E. ½ E.				
29.	−36 11	116 48	Direct.	−66 53	N.N.E.	+84	−26	−66 00	Unsteady.
			Needle N.	−67 11	N.N.E.				
			Needle S.	−66 51	N.N.E.				
			Needle N.S.	−66 57	N.N.E.				
30.	−35 07	117 28	Direct.	−66 15	N.N.E.	+84	−26	−65 24	Unsteady.
			Needle N.	−66 25	N.N.E.				
			Needle S.	−66 50	N.N.E.				
			Needle N.S.	−65 59	N.N.E.				
April 7.	−35 02	117 56	Direct.	−64 42	....	....	−26	−64 55	At the tents, King George's Sound.
			Needle N.	−64 39					
			Needle S.	−64 08					
			Needle N.S.	−64 39					
			Mag. N.	−64 18					
			Mag. S.	−64 29					
11.	−35 02	117 56	Direct.	−65 22	....	....	+18	−64 52	At the tents, King George's Sound. The readings of ne dle A. being very discordant put i needle B., the change having been made between the 7th an 10th of April*.
			Needle N.	−65 04					
			Needle S.	−64 48					
			Needle N.S.	−65 13					
			Mag. N.	−65 11					
			Mag. S.	−65 15					

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* Needle A.		Needle B.	
Face east	64 29	Face west	° ′ 65 13

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1845.	° ′	° ′		° ′		′	′	° ′ ° ′	
Apr. 12.	−35 02	117 56	Direct.	−65 34	…………	………	+18	−65 07	At the tents, King George's Sound.*
			Needle N.	−65 39					
			Needle S.	−65 07					
			Needle N.S.	−65 25					
			Mag. N.	−65 21					
			Mag. S.	−65 23					
19.	−35 02	117 56	Direct.	−65 15	S.	−21	+18	−65 02	
			Needle N.	−64 55	S.				
			Needle S.	−64 32	S.				
			Direct.	−65 15	S.				
20.	−35 06	117 55	Direct.	−66 29	S.E. by E.	+12	+18	−65 59 } 65 59	Unsteady.
			Direct.	−65 58	S. by E.	−18	+18	−65 58	
23.	−35 30	114 35	Direct.	−66 33	N.W.	+92	+18	−64 54	Very unsteady.
			Needle N.	−67 30	N.W.				
			Needle S.	−66 30	N.W.				
			Needle N.S.	−66 35	N.W.				
			Direct.	−66 30	N.W.				
25.	−32 24	111 26	Direct.	−64 03	N.W. by N.	+88	+18	−62 22	Moderate breeze, table steady.
			Needle N.	−64 22	N.W. by N.				
			Needle S.	−63 31	N.W. by N.				
			Needle N.S.	−63 58	N.W. by N.				
			Mag. N.	−64 43	N.W. by N.				
			Mag. S.	−64 06	N.W. by N.				
			Direct.	−64 13	N.W. by N.				
27.	−29 16	106 49	Direct.	−60 10	W.N.W.	+72	+18	−59 30	Very unsteady.
			Needle N.	−60 56	W.N.W.				
			Needle S.	−60 16	W.N.W.				
			Needle N.S.	−60 30	W.N.W.				
			Direct.	−60 53	W.N.W.				
28.	−27 35	106 32	Direct.	−58 47	W. by N.	+61	+18	−57 26	A heavy swell, unsteady.
			Needle N.	−58 46	W. by N.				
			Needle S.	−58 51	W. by N.				
			Needle N.S.	−58 24	W. by N.				
			Mag. N.	−58 53	W. by N.				
			Mag. S.	−58 53	W. by N.				
			Direct.	−58 43	W. by N.				
29.	−25 46	104 55	Direct.	−56 54	N.W.	+88	+18	−55 05	Very unsteady.
			Needle N.	−56 54	N.W.				
			Needle S.	−56 41	N.W.				
			Direct.	−56 54	N.W.				
May 1.	−23 58	99 06	Direct.	−55 48	N.W.	+87	+18	−53 46	Unsteady.
			Needle N.	−55 30	N.W.				
			Needle S.	−55 22	N.W.				
			Needle N.S.	−55 28	N.W.				
2.	−24 01	97 25	Direct.	−55 37	W. ½ N.	+56	+18	−54 18	Unsteady.
			Needle N.	−55 58	W. ½ N.				
			Needle S.	−55 01	W. ½ N.				
			Needle N.S.	−55 32	W. ½ N.				

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* Captain FITZROY having left a memorandum at King George's Sound stating that he had found local magnetic disturbance at King George's Sound, the Inclination was observed on the opposite side of the bay, on the same day as at the tents: needle B gave as follows (no correction being here applied for Index in either case) :—

At the tents.		On the opposite side of the bay.	
Face west…………	−65° 13′	Face west…………	−65° 16′
Face east…………	−65 10	Face east…………	−65 30
Mean………	−65 11·5	Mean………	−65 23

The distance between the two stations was between three and four miles.

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
May 3.	−23 50	95 56	Direct.	−55 38	W. ½ N.	+56	+18	−54 26		Unsteady.
			Needle N.	−56 17	W. ½ N.					
			Needle S.	−55 00	W. ½ N.					
			Needle N.S.	−55 38	W. ½ N.					
			Direct.	−55 48	W. ½ N.					
4.	−24 17	93 50	Direct.	−55 43	W.N.W.	+72	+18	−54 07		Unsteady.
			Needle N.	−56 08	W.N.W.					
			Needle S.	−55 08	W.N.W.					
			Needle N.S.	−55 33	W.N.W.					
			Direct.	−55 35	W.N.W.					
5.	−24 02	92 07	Direct.	−54 42	N.W.	+88	+18	−52 44		Cross sea, with rolling motion.
			Needle N.	−54 39	N.W.					
			Needle S.	−54 10	N.W.					
7.	−21 44	89 38	Direct.	−53 33	N.W. ½ W.	+83	+18	−51 45		Cross sea, with rolling motion.
			Needle N.	−53 47	N.W. ½ W.					
			Needle S.	−53 03	N.W. ½ W.					
			Needle N.S.	−53 19	N.W. ½ W.					
8.	−20 38	87 50	Direct.	−52 48	W. ½ N.	+54	+18	−51 33		Very unsteady.
			Needle N.	−53 18	W. ½ N.					
			Needle S.	−51 58	W. ½ N.					
			Needle N.S.	−53 00	W. ½ N.					
			Direct.	−52 45	W. ½ N.					
9.	−20 37	85 02	Direct.	−52 37	W. ½ N.	+55	+18	−51 21		Unsteady.
			Needle N.	−53 16	W. ½ N.					
			Needle S.	−52 18	W. ½ N.					
			Needle N.S.	−52 20	W. ½ N.					
			Direct.	−52 20	W. ½ N.					
10.	−20 25	82 00	Direct.	−52 31	W. ¾ N.	+68	+18	−51 05		Fresh breeze, table unsteady.
			Needle N.	−52 30	W. ¾ N.					
			Needle S.	−52 48	W. ¾ N.					
			Needle N.S.	−52 26	W. ¾ N.					
			Direct.	−52 31	W. ¾ N.					
			Mag. N.	−52 19	W. ¾ N.					
			Mag. S.	−52 29	W. ¾ N.					
11.	−20 36	79 10	Direct.	−53 10	W. ¾ N.	+68	+18	−51 46		Steady.
			Needle N.	−53 03	W. ¾ N.					
			Needle S.	−52 41	W. ¾ N.					
			Needle N.S.	−53 18	W. ¼ N.					
			Direct.	−53 17	W. ¼ N.					
12.	−20 44	78 31	Direct.	−52 15	S.	+15	+18	−52 00	−52 00	Light air, table steady. The observations at N.W., N.N.W., and N. have not been included in the mean.
			Needle N.	−52 46	S.					
			Direct.	−52 42	S.S.W.	+19	+18	−52 19		
			Needle N.	−53 05	S.S.W.					
			Direct.	−53 10	S.W.	+30	+18	−52 15		
			Needle N.	−52 57	S.W.					
			Direct.	−53 11	W.S.W.	+44	+18	−52 18		
			Needle N.	−53 30	W.S.W.					
			Direct.	−53 06	W.	+51	+18	−52 11		
			Needle N.	−53 34	W.					
			Direct.	−53 01	W.N.W.	+72	+18	−51 45		
			Needle N.	−53 30	W.N.W.					
			Direct.	−52 33	N.W.	+86	+18	−50 44		
			Needle N.	−52 23	N.W.					
			Direct.	−51 59	N.N.W.	+68	+18	−50 53		
			Needle N.	−52 38	N.N.W.					
			Direct.	−52 31	N.	+72	+18	−51 10		
			Needle N.	−52 49	N.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
May 12.	−20 44	78 31	Direct.	−52 58	N.N.E.	+68	+18	−51 33	−52 00	Light air, table steady. The observations at N.W., N.N.W., and N. have not been included in the mean.
			Needle N.	−53 04	N.N.E.					
			Direct.	−53 18	N.E.	+86	+18	−51 40		
			Needle N.	−53 30	N.E.					
			Direct.	−53 15	E.N.E.	+72	+18	−52 02		
			Needle N.	−53 49	E.N.E.					
13.	−20 39	77 43	Direct.	−53 15	S.E.	+30	+18	−52 34	−51 58	A rolling motion, not very steady at some points.
			Needle N.	−53 29	S.E.					
			Direct.	−53 25	E.	+51	+18	−52 15		
			Needle N.	−53 41	E.					
			Direct.	−53 05	N.E.	+86	+18	−51 42		
			Needle N.	−53 47	N.E.					
			Direct.	−52 42	N.	−72	+18	−51 28		
			Needle N.	−53 13	N.					
			Direct.	−52 58	N.W.	+86	+18	−51 30		
			Needle N.	−53 30	N.W.					
			Direct.	−53 27	W.	+51	+18	−52 16		
			Needle N.	−53 41	W.					
16.	−20 26	70 36	Direct.	−53 52	W. by N.	+62	+18	−52 19		Unsteady.
		69 00	Needle N.	−53 49	W. by N.					
			Needle S.	−53 15	W. by N.					
			Needle N.S.	−53 47	W. by N.					
			Direct.	−53 30	W. by N.					
17.	−20 34	69 24	Direct.	−54 05	W. by N.	+62	+18	−52 44	−53 01	Very unsteady.
			Needle N.	−54 10	W. by N.					
			Needle S.	−53 52	W. by N.					
			Needle N.S.	−54 01	W. by N.					
			Direct.	−54 10	W. by N.					
	−20 34	69 24	Direct.	−54 41	S.W. by W.	+37	+18	−53 18		Very unsteady.
			Needle N.	−54 23	S.W. by W.					
			Needle S.	−54 00	S.W. by W.					
			Needle N.S.	−53 58	S.W. by W.					
			Mag. N.	−54 15	S.W. by W.					
			Mag. S.	−54 09	S.W. by W.					
			Direct.	−54 06	S.W. by W.					
18.	−21 08	68 04	Direct.	−54 21	W. by N.	+62	+18	−53 01		Unsteady.
19.	−21 11	67 54	Direct.	−55 10	W. by N.	+62	+18	−53 46		Steady.
			N.	−56 07	W. by N.					
			S.	−54 54	W. by N.					
			N.S.	−55 09	W. by N.					
			Mag. N.	−55 10	W. by N.					
20.	−21 12	67 29	Direct.	−55 23	W. by N.	+62	+18	−53 59		Table unsteady.
			Needle N.	−55 46	W. by N.					
			Needle S.	−54 56	W. by N.					
			Needle N.S.	−55 11	W. by N.					
			Direct.	−55 19	W. by N.					
21.	−21 01	66 50	Direct.	−55 19	W. by N.	+62	+18	−53 49		Unsteady.
			Needle N.	−55 35	W. by N.					
			Needle S.	−54 40	W. by N.					
			Needle N.S.	−55 11	W. by N.					
			Mag. N.	−55 17	W. by N.					
			Mag. S.	−54 40	W. by N.					
			Direct.	−55 17	W. by N.					
22.	−20 40	62 58	Direct.	−55 13	W. by N.	+62	+18	−53 53		Table steady.
			Needle N.	−55 32	W. by N.					
			Needle S.	−54 59	W. by N.					
			Needle N.S.	−55 09	W. by N.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
May 27.	−20 09	57 31	Direct.	−53 53	…………	………	+18	−53 38		On shore at Mauritius.
			Needle N.	−54 27						
			Needle S.	−53 29						
			Needle N.S.	−53 59						
			Mag. N.	−53 57						
			Mag. S.	−53 52						
30.	−21 50	53 25	Direct.	−55 50	s.w. by w.	+32	+18	−54 51		Unsteady.
			Needle N.	−56 20	s.w. by w.					
			Needle S.	−55 05	s.w. by w.					
			Needle N.S.	−55 30	s.w. by w.					
June 3.	−26 26	48 20	Direct.	−60 20	N.W. by W.	+80	+18	−58 46		Unsteady.
			Needle N.	−60 40	N.W. by W.					
			Needle S.	−59 57	N.W. by W.					
			Needle N.S.	−60 38	N.W. by W.					
4.	−27 14	45 50	Direct.	−60 02	N.W. by W.	+80	+18	−58 32		Very unsteady.
			Needle N.	−60 46	N.W. by W.					
			Needle S.	−59 18	N.W. by W.					
			Needle N.S.	−60 32	N.W. by W.					
5.	−28 02	42 40	Direct.	−59 48	N.W. by W.	+80	+18	−58 10		Very unsteady.
8.	−28 57	37 45	Direct.	−60 02	W.	+50	+18	−59 14		Steady.
			Needle N.	−60 30	W.					
			Needle S.	−59 51	W.					
			Needle N.S.	−61 40	W.					
			Mag. N.	−60 08	W.					
			Mag. S.	−60 02	W.					
11.	−30 27	33 41	Direct.	−58 12	W.N.W.	+72	+18	−56 37		Very unsteady, a heavy sea.
			Needle N.	−58 03	W.N.W.					
13.	−31 06	31 26	Direct.	−58 59	W. by S. ½ S.	+38	+18	−57 24		Very unsteady.
			Needle N.	−59 04	W. by S. ½ S.					
			Needle S.	−57 33	W. by S. ½ S.					
			Mag. N.S.	−60 12	W. by S. ½ S.					
			Direct.	−58 55	W. by S. ½ S.					
17.	−35 40	21 40	Direct.	−56 56	W. by N.	+62	+18	−55 31		
			Needle N.	−57 00	W. by N.					
			Mag. N.S.	−56 39	W. by N.					
			Direct.	−56 49	W. by N.					
23.	Simon's Bay, Cape of Good Hope, for local attraction.		Direct.	−53 29	S.	+27	+18	−53 45	−53 24	
			Needle N.	−54 55	S.					
			Direct.	−53 43	S.E.	+26	+18	−53 37		
			Needle N.	−54 59	S.E.					
			Direct.	−54 38	E.	+51	+18	−53 32		
			Needle N.	−54 44	E.					
			Direct.	−54 40	N.E.	+87	+18	−53 06		
			Needle N.	−55 01	N.E.					
			Direct.	−54 31	N.	+75	+18	−53 12		
			Needle N.	−54 59	N.					
			Direct.	−54 45	N.W.	+88	+18	−53 00		
			Needle N.	−54 54	N.W.					
			Direct.	−54 46	W.	+51	+18	−53 39		
			Needle N.	−54 51	W.					
24.	On shore in the Dockyard, in Simon's Bay.		Direct.	−53 53	…………	………	+18	−53 37		
			Needle N.	−54 24						
			Needle S.	−53 12						
			Mag. N.S.	−54 09						

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′			′	° ′	° ′	
ne 30.	−33 56	18 29	Direct.	−53 56						
			Needle N.	−54 15						
			Needle S.	−52 47						
			Mag. N.S.	−54 06	....	....	+18	−53 22		
			Mag. N.	−53 29						
			Mag. S.	−53 23						
uly 2.	−33 56	18 29	Direct.	−53 41						
			Needle N.	−54 11						
			Needle S.	−52 55						
			Mag. N.S.	−54 15	....	....	+18	−53 27	−53 29	Observed at the Magnetic Observatory, Cape of Good Hope.
			Mag. N.	−53 49						
			Mag. S.	−53 41						
11.	−33 56	18 29	Direct.	−53 59						
			Needle N.	−54 08						
			Needle S.	−53 17						
			Mag. N.S.	−54 12	....	....	+18	−53 37		
			Mag. N.	−53 54						
			Mag. S.	−53 59						

Observations of the INCLINATION made on board Her Majesty's hired Bark "Pagoda," with Needle 1 (Fox No. 1). Face West. Time usually two hours before Noon.

Observer, Lieut. H. CLERK, Royal Artillery.

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections. Ship's attraction.	Corrections. Index.	Corrected Inclination.		Remarks.
1844.	° ′	° ′		° ′		′	′	° ′	° ′	
Nov. 10.	Magnetic Observatory, Cape of Good Hope.		Direct.	−53 56	Observed on shore.	......	+08	−53 31		Needle A. used as deflector, adjusted at 40° from the apparent dip.
			N.	−53 25						
	−33 56	18 29	S.	−53 37						
21.			Direct.	−53 53	Observed on shore.	......	+08	−53 31		
			N.	−53 25						
			S.	−53 37						
Dec. 19.	−34 12	18 26	Direct.	−54 15	Observed on shore.	......	+08	−53 50		Observed in the dock-yard at Simon's Bay.
			N.	−53 43						
			S.	−53 55						
1845. Jan. 9.	Working out of False Bay.		Direct.	−54 28	s.E. by s. ½ s.	+22	+08	−53 48	−53 34	A strong south-east wind, table very unsteady 2 P.M.
			N.	−54 03	s.E. by s. ½ s.					
			S.	−54 25	s.E. by s. ½ s.					
			Direct.	−54 48	w. ½ s.	+51	+08	−53 20		Table very unsteady.
			N.	−53 58	w. ½ s.					
			S.	−54 10	w. ½ s.					
10.	−34 44	17 50	Direct.	−54 18	w. by N.	+61	+08	−52 56		Table unsteady.
			N.	−53 48	w. by N.					
			S.	−54 08	w. by N.					
13.	−35 12	13 28	Direct.	−52 33	s.w. by w.	+37	+08	−51 35		Table steady.
			N.	−52 03	s.w. by w.					
			S.	−52 25	s.w. by w.					
14.	−37 25	13 24	Direct.	−52 48	s.w. by w.	+17	+13	−51 44		Up to the 13th of January the deflectors were at 40° from dip; on and after the 14th they were at the dip, so that the same observations gave dip and intensity.
			N.	−51 54	s.w. by w.					
			S.	−52 05	s.w. by w.					
			N.S.	−52 08	s.w. by w.					
15.	−38 37	14 27	Direct.	−54 58	N.w. by w.	+79	+13	−52 39		Very unsteady.
			N.	−53 48	N.w. by w.					
			S.	−54 03	N.w. by w.					
			N.S.	−53 58	N.w. by w.					
16.	−39 10	14 41	Direct.	−55 33	s.w. by w. ½ w.	+35	+13	−54 14		Table steady.
			N.	−54 20	s.w. by w. ½ w.					
			S.	−54 58	s.w. by w. ½ w.					
			N.S.	−55 18	s.w. by w. ½ w.					
17.	−40 21	14 29	Direct.	−56 18	s.w. by w.	+35	+13	−55 10		Much motion.
			N.	−55 40	s.w. by w.					
			S.	−55 52	s.w. by w.					
			N.S.	−56 00	s.w. by w.					
18.	−42 50	13 00	Direct.	−56 38	s.s.w.	+12	+13	−55 34		Much motion.
			N.	−55 40	s.s.w.					
			S.	−55 48	s.s.w.					
			N.S.	−55 50	s.s.w.					
19.	−44 50	13 19	Direct.	−57 18	s.w. by s.	+15	+13	−56 14		Much motion.
			N.	−56 25	s.w. by s.					
			S.	−56 35	s.w. by s.					
			N.S.	−56 30	s.w. by s.					
21.	−47 40	12 25	Direct.	−56 43	s. by E.	+06	+11	−56 29		A calm, very unsteady.
			N.	−56 50	s. by E.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections. Ship's attraction.	Corrections. Index.	Corrected Inclination.	Remarks.
1845.	° ′	° ′		° ′		′	′	° ′ ° ′	
Jan. 22.	−48 35	10 51	Direct.	−57 23	s.w. by s.	+15	+13	−56 44	Table steady.
			N.	−57 17	s.w. by s.				
			S.	−57 03	s.w. by s.				
			N.S.	−57 05	s.w. by s.				
23.	−50 30	10 25	Direct.	−57 33	s.w. ½ s.	+15	+13	−57 02	Table steady.
			N.	−57 33	s.w. ½ s.				
			S.	−57 45	s.w. ½ s.				
			N.S.	−57 10	s.w. ½ s.				
24.	−51 48	9 33	Direct.	−58 13	s.w. by w.	+25	+13	−57 13	1 P.M. table steady.
			N.	−57 55	s.w. by w.				
			S.	−57 37	s.w. by w.				
			N.S.	−57 40	s.w. by w.				
25.	−52 53	7 53	Direct.	−58 13	s.w. by w.	+25	+13	−57 03	Table rather unsteady.
			N.	−57 20	s.w. by w.				
			S.	−57 40	s.w. by w.				
			N.S.	−57 30	s.w. by w.				
26.	−53 52	6 07	Direct.	−58 23	w. by s.	+46	+13	−57 01	Table very steady.
			N.	−57 55	w. by s.				
			S.	−57 40	w. by s.				
			N.S.	−58 03	w. by s.				
27.	−55 08	5 50	Direct.	−58 38	s.s.w. ½ w.	+16	+13	−57 26	Table very unsteady.
			N.	−57 28	s.s.w. ½ w.				
			S.	−57 25	s.s.w. ½ w.				
			N.S.	−58 10	s.s.w. ½ w.				
30.	−60 43	4 00	Direct.	−61 23	s.	−08	+24	−61 06	
			N.S.	−61 20	s.				
			Direct.	−61 03	s.e. by e.	+22	+24	−60 14 } −59 58	Table unsteady.
			N.S.	−60 58	s.e. by e.				
			Direct.	−60 08	n.	+85	+24	−58 35	
			N.S.	−60 40	n.				
31.	−61 05	9 03	Direct.	−61 32	s.e. by s.	00	+13	−61 01	Table steady.
			N.	−61 35	s.e. by s.				
			S.	−61 13	s.e. by s.				
			N.S.	−60 35	s.e. by s.				
Feb. 2.	−61 54	16 23	Direct.	−64 18	e.s.e.	+30	+13	−63 00	Table unsteady.
			N.	−63 30	e.s.e.				
			S.	−63 30	e.s.e.				
			N.S.	−63 33	e.s.e.				
3.	−61 50	19 13	Direct.	−65 13	e.s.e.	+25	+13	−63 55	Table very steady.
			N.	−64 18	e.s.e.				
			S.	−64 28	e.s.e				
			N.S.	−64 13	e.s.e.				
4.	−62 00	20 25	Direct.	−65 33	s.s.e.	−15	+13	−64 55	Table very steady.
			N.	−64 43	s.s.e.				
			S.	−64 35	s.s.e.				
			N.S.	−64 40	s.s.e.				
6.	−64 20	24 05	Direct.	−67 03	s.s.e.	−18	+13	−66 37	Table very steady.
			N.	−66 13	s.s.e.				
			S.	−66 20	s.s.e.				
			N.S.	−66 30	s.s.e.				
7.	−65 34	28 30	Direct.	−67 18	s.s.e. ½ e.	−16	+13	−66 59	Table very steady.
			N.	−67 00	s.s.e. ½ e.				
			S.	−66 40	s.s.e. ½ e.				
			N.S.	−66 45	s.s.e. ½ e.				
9.	−66 30	36 46	Direct.	−69 13	e.	+40	+13	−68 16	Table very steady.
			N.	−69 10	e.				
			S.	−69 03	e.				
			N.S.	−69 08	e.				

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
	° ′	° ′		° ′		′	′	° ′	° ′	
1845. Feb. 10.	−66 43	38 49	Direct.	−69 28	S.S.W.	−26	+13	−69 22		Table very steady.
			N.	−69 08	S.S.W.					
			S.	−69 03	S.S.W.					
			N.S.	−68 58	S.S.W.					
11.	−67 35	39 31	Direct.	−71 28	N.E.	+89	+13	−69 49		Table very steady 8 P.M.
			N.	−71 43	N.E.					
			S.	−71 23	N.E.					
12.	−66 45	39 23	Direct.	−70 08	S.S.E.	−30	+13	−70 12		Table very unsteady.
			N.	−70 10	S.S.E.					
			S.	−69 45	S.S.E.					
			N.S.	−69 35	S.S.E.					
13.	−67 00	40 07	Direct.	−70 43	E.N.E.	+66	+13	−69 39		Table steady.
			N.	−71 10	E.N.E.					
			S.	−71 28	E.N.E.					
			N.S.	−70 30	E.N.E.					
16.	−64 52	38 37	Direct.	−68 32	N.N.E.	+85	+32	−66 35*	68 40	Table very unsteady, ship pitching much.
			Direct.	−68 53	S. ¾ E.	−26	+13	−68 40		
			N.	−68 08	S. ¾ E.					
			S.	−68 20	S. ¾ E.					
17.	−64 52	40 12	Direct.	−70 08	N. by W.	+80	+13	−68 44		Table very unsteady, heavy swell.
			N.	−70 32	N. by W.					
			S.	−70 25	N. by W.					
			N.S.	−70 02	N. by W.					
18.	−64 22	40 49	Direct.	−68 13	S. by E.	−29	+13	−68 40		Table very unsteady.
			N.	−68 25	S. by E.					
			S.	−68 35	S. by E.					
19.	−63 49	42 00	Direct.	−70 33	E. by S.	+28	+13	−69 36		Table very unsteady 6 P.M.
			N.	−70 03	E. by S.					
			S.	−70 20	E. by S.					
			N.S.	−70 13	E. by S.					
20.	−63 22	45 35	Direct.	−70 53	S.E. by E. ½ E.	+13	+21	−70 03		Table very unsteady.
			S.	−70 25	S.E. by E. ½ E.					
			N.S.	−70 33	S.E. by E. ½ E.					
21.	−63 36	46 41	Direct.	−70 03	S.S.E.	−28	+13	−70 02		Table unsteady.
			N.	−70 18	S.S.E.					
			S.	−69 35	S.S.E.					
			N.S.	−69 10	S.S.E.					
24.	−62 36	51 40	Direct.	−69 48	E.	+41	+24	−68 39	69 13	Taken at 10 A.M., table very unsteady, ship pitching violently.
			N.S.	−69 40	E.					
			Direct.	−70 28	E.	+41	+13	−69 46		Taken at 5 P.M.
			N.	−70 13	E.					
			S.	−71 20	E.					
25.	−61 25	53 38	Direct.	−71 28	E.S.E.	+12	+13	−70 46		Table unsteady.
			N.	−71 18	E.S.E.					
			S.	−71 00	E.S.E.					
			N.S.	−70 58	E.S.E.					
26.	−61 17	57 28	Direct.	−72 13	S.E. ½ E.	−11	+13	−72 01		Table unsteady.
			N.	−72 43	S.E. ½ E.					
			S.	−71 48	S.E. ½ E.					
			N.S.	−71 28	S.E. ½ E.					
27.	−61 00	64 03	Direct.	−73 28	S.E. ½ S.	−21	+13	−73 27		Table steady.
			N.	−73 15	S.E. ½ S.					
			S.	−73 38	S.E. ½ S.					
			N.S.	−72 55	S.E. ½ S.					
28.	−61 36	70 46	Direct.	−73 43	S.S.E.	−38	+13	−74 02		Table unsteady, heavy swell.
			N.	−73 55	S.S.E.					
			S.	−73 35	S.S.E.					
			N.S.	−73 15	S.S.E.					

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* Error, probably in the degree noted; result not included in the mean.

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
Mar. 1.	−62 10	72 25	Direct.	−74 13	s.s.e.	−38	+13	−74 35		Table steady.
			N.	−74 23	s.s.e.					
			S.	−74 20	s.s.e.					
			N.S.	−73 43	s.s.e.					
2.	−62 40	76 09	Direct.	−74 28	s.	−46	+13	−74 50		Table very steady.
			N.	−74 13	s.					
			S.	−74 23	s.					
			N.S.	−74 03	s.					
3.	−64 20	79 38	Direct.	−75 53	s. by w. ½ w.	−43	+13	−76 34		Table unsteady.
			N.	−76 45	s. by w. ½ w.					
			S.	−76 27	s. by w. ½ w.					
			N.S.	−75 10	s. by w. ½ w.					
5.	−61 38	84 40	Direct.	−76 13	s.e.	−23	+13	−76 27		Table unsteady.
			N.	−76 10	s.e.					
			S.	−76 38	s.e.					
			N.S.	−76 08	s.e.					
6.	−60 42	80 12	Direct.	−77 23	n.e. ½ n.	+82	+13	−75 43		Table unsteady.
			N.	−77 08	n.e. ½ n.					
			S.	−77 23	n.e. ½ n.					
			N.S.	−77 18	n.e. ½ n.					
7.	−61 20	91 09	Direct.	−76 28	s. by e.	−49	+13	−77 23	77 35	Table very unsteady, taken at 10 a.m.
			N.	−77 20	s. by e.					
			S.	−77 18	s. by e.					
			N.S.	−76 02	s. by e.					
	−61 26	91 20	Direct.	−77 18	s.w. by s.	−35	+13	−77 46		Taken at 5 p.m. in consequence of the a.m. observations being unsatisfactory. The aurora was very brilliant all the previous and succeeding nights.
			N.	−77 28	s.w. by s.					
			S.	−77 50	s.w. by s.					
			N.S.	−77 00	s.w. by s.					
8.	−61 14	92 03	Direct.	−79 03	e.	+26	+13	−78 26		Table steady. Table steady, light N.W. swell.
			N.	−79 43	e.					
			S.	−79 05	e.					
			N.S.	−78 30	e.					
9.	−60 35	92 25	Direct.	−78 13	e.	+26	+13	−77 30		Table unsteady.
			N.	−78 25	e.					
			S.	−78 15	e.					
			N.S.	−77 42	e.					
10.	−60 03	95 36	Direct.	−76 27	s.e. ½ s.	−37	+13	−77 35		Table very unsteady.
			N.	−77 30	s.e. ½ s.					
			S.	−77 35	s.e. ½ s.					
11.	−59 52	99 30	Direct.	−80 03	e. ½ s.	+15	+13	−79 21	79 36	Table very unsteady, taken at 10 a.m.
			N.	−80 23	e. ½ s.					
			S.	−79 25	e. ½ s.					
			N.S.	−79 23	e. ½ s.					
	−59 59	99 39	Direct.	−80 28	e. ½ n.	+30	+13	−79 51		Table steady, taken at 6 p.m.
			N.	−81 05	e. ½ n.					
			S.	−80 50	e. ½ n.					
			N.S.	−79 53	e. ½ n.					
13.	−57 35	99 28	Direct.	−79 18	e. by s.	+11	+14	−78 36		Table very unsteady, taken at 6 p.m.
			N.S.	−79 03	e. by s.					
14.	−56 53	101 24	Direct.	−78 33	e. by s.	+12	+13	−78 40		Table very unsteady.
			N.	−79 38	e. by s.					
			S.	−79 22	e. by s.					
			N.S.	−78 48	e. by s.					
15.	−55 52	103 06	Direct.	−79 18	e. by n.	+39	+13	−78 56		Table very unsteady.
			N.	−80 28	e. by n.					
			S.	−80 03	e. by n.					
			N.S.	−79 23	e. by n.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.										
Mar. 16.	° ′ −54 48	° ′ 106 04	Direct.	° ′ −79 33	N.E.	′ +78	′ +13	° ′ −78 09	° ′	Table very unsteady.
			N.	−80 03	N.E.					
			S.	−79 25	N.E.					
			N.S.	−79 38	N.E.					
17.	−54 17	108 05	Direct.	−78 23	S.E.	−30	+13	−79 16	−78 49	Table very unsteady, ship pitching violently.
			N.	−79 38	S.E.					
			S.	−78 55	S.E.					
			Direct.	−78 38	E.	+24	+13	−78 21		
			N.	−78 58	E.					
			S.	−79 18	E.					
18.	−53 00	110 08	Direct.	−79 28	N.N.E. ½ E.	+82	+13	−77 28		Table very unsteady.
			N.	−78 55	N.N.E. ½ E.					
			S.	−78 48	N.N.E. ½ E.					
			N.S.	−79 00	N.N.E. ½ E.					
19.	−51 20	111 23	Direct.	−78 08	N.N.E. ½ E.	+85	+21	−76 41		Table very unsteady, heavy swell.
			S.	−78 48	N.N.E. ½ E.					
			N.S.	−78 25	N.N.E. ½ E.					
20.	−49 01	111 47	Direct.	−77 38	N.E. by N.	+82	+13	−76 30		Table unsteady, very heavy swell.
			N.	−78 38	N.E. by N.					
			S.	−78 30	N.E. by N.					
			N.S.	−77 33	N.E. by N.					
22.	−47 21	115 15	Direct.	−76 43	E.N.E.	+58	+13	−75 31		Table steady, light swell.
			N.	−77 13	E.N.E.					
			S.	−77 03	E.N.E.					
			N.S.	−75 48	E.N.E.					
25.	−43 20	116 52	Direct.	−73 23	N. ½ E.	+76	+13	−72 45		Table very unsteady, heavy swell from W.
			N.	−75 45	N. ½ E.					
			S.	−74 48	N. ½ E.					
			N.S.	−72 58	N. ½ E.					
26.	−41 18	116 09	Direct.	−71 33	N. by W.	+80	+13	−70 11		Table unsteady, light swell.
			N.	−71 33	N. by W.					
			S.	−72 15	N, by W.					
			N.S.	−71 33	N. by W.					
27.	−38 52	116 15	Direct.	−70 23	N. by W.	+80	+13	−68 49		Table steady.
			N.	−70 45	N. by W.					
			S.	−70 50	N. by W.					
			N.S.	−69 28	N. by W.					
28.	−37 03	116 57	Direct.	−68 33	N. by E.	+83	+13	−66 46		Table very steady, nearly calm.
			N.	−68 48	N. by E.					
			S.	−68 13	N. by E.					
			N.S.	−67 53	N. by E.					
29.	−36 12	−116 50	Direct.	−67 30	N.N.E.	+84	+13	−65 28		Table unsteady.
			N.	−67 13	N.N.E.					
			S.	−66 55	N.N.E.					
			N.S.	−66 43	N.N.E.					
30.	−35 18	117 07	Direct.	−67 28	N.E. ½ E.	+86	+13	−65 48		Table unsteady.
			N.	−68 00	N.E. ½ E.					
			S.	−67 48	N.E. ½ E.					
			N.S.	−66 30	N.E. ½ E.					
April 7.	−35 02	117 56	Direct.	−65 28	Observed on shore.	......	+13	−65 11	−65 11	The observations were made at the same place that was used by Captains Flinders and Fitzroy.
	King George's Sound.		N.	−65 36						
			S.	−65 30						
			N.S.	−65 03						
11.	King George's Sound.		Direct.	−65 28	Observed on shore.	......	+13	−65 11		
			N.	−65 28						
			S.	−65 31						
			N.S.	−65 09						

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
April 19.	At anchor in the Sound.		Direct.	−65 02	S.S.W.	−16	+24	−64 46	−64 51	The table was very steady during these observations.
			N.S.	−64 46	S.S.W.					
		To obtain corrections for the ship's attraction.	Direct.	−65 49	S.W.	+01	+24	−65 12		
			N.S.	−65 25	S.W.					
			Direct.	−65 54	W.S.W.	+23	+24	−64 57		
			N.S.	−65 33	W.S.W.					
			Direct.	−66 02	W.	+46	+24	−64 41		
			N.S.	−65 39	W.					
			Direct.	−66 23	W.N.W.	+70	+24	−64 39		
			N.S.	−66 03	W.N.W.					
			Direct.	−66 35	N.W.	+92	+24	−64 30		
			N.S.	−66 16	N.W.					
			Direct.	−66 50	N.N.W.	+84	+24	−64 52		
			N.S.	−66 29	N.N.W.					
			Direct.	−66 29	N.	+84	+24	−64 34		
			N.S.	−66 14	N.					
			Direct.	−66 48	N.N.E.	+83	+24	−64 50		
			N.S.	−66 26	N.N.E.					
			Direct.	−66 35	N.E.	+92	+24	−64 26		
			N.S.	−66 09	N.E.					
			Direct.	−66 27	E.N.E.	+70	+24	−64 40		
			N.S.	−66 00	E.N.E.					
			Direct.	−66 37	E.	+46	+24	−65 19		
			N.S.	−66 21	E.					
			Direct.	−66 16	E.S.E.	+23	+24	−65 11		
			N.S.	−65 40	E.S.E.					
			Direct.	−65 52	S.E.	+01	+24	−65 11		
			N.S.	−65 19	S.E.					
			Direct.	−65 13	S.S.E.	−16	+24	−64 58		
			N.S.	−64 58	S.S.E.					
			Direct.	−65 11	S.	−21	+24	−64 57		
			N.S.	−64 46	S.					
23.	−35 36	114 44	Direct.	−66 53	N.W.	+92	+13	−65 28		Table unsteady.
			N.	−67 45	N.W.					
			S.	−67 40	N.W.					
			N.S.	−66 33	N.W.					
24.	−34 16	113 01	Direct.	−66 33	N.W. by N.	+88	+13	−64 44		Table unsteady.
			N.	−66 28	N.W. by N.					
			S.	−66 25	N.W. by N.					
			N.S.	−66 15	N.W. by N.					
25.	−32 32	111 36	Direct.	−63 48	N.W. by N.	+88	+13	−62 14		Table unsteady.
			N.	−64 25	N.W. by N.					
			S.	−63 55	N.W. by N.					
			N.S.	−63 33	N.W. by N.					
27.	−29 20	106 55	Direct.	−60 58	W.N.W.	+72	+13	−59 19		Table steady.
			N.	−61 05	W.N.W.					
			S.	−60 20	W.N.W.					
			N.S.	−60 33	W.N.W.					
28.	−27 47	106 36	Direct.	−58 28	N. by W. ½ W.	+76	+13	−57 17		Table very unsteady, heavy swell.
			N.	−58 10	N. by W. ½ W.					
			S.	−58 25	N. by W. ½ W.					
			N.S.	−60 00	N. by W. ½ W.					
29.	−26 00	105 11	Direct.	−56 38	N.W.	+88	+13	−55 09		Table very unsteady, very heavy swell.
			N.	−56 48	N.W.					
			S.	−57 08	N.W.					
			N.S.	−56 45	N.W.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
May 1.	−24 00	99 23	Direct.	−55 18	W.	+51	+13	−54 28		Table very unsteady, considerable motion.
			N.	−55 55	W.					
			S.	−56 13	W.					
			N.S.	−54 43	W.					
2.	−24 01	97 30	Direct.	−55 03	W.	+51	+13	−54 03		Table steady.
			N.	−55 20	W.					
			S.	−55 28	W.					
			N.S.	−54 35	W.					
3.	−24 00	96 06	Direct.	−55 18	W. ½ N.	+56	+13	−54 16		Table steady.
			N.	−55 13	W. ½ N.					
			S.	−55 30	W. ½ N.					
			N.S.	−55 38	W. ½ N.					
6.	−22 47	91 00	Direct.	−54 28	N.W.	+87	+13	−52 49		Table very unsteady, heavy swell from W.
			N.	−54 40	N.W.					
			S.	−54 28	N.W.					
			N.S.	−54 18	N.W.					
7.	−21 50	89 44	Direct.	−53 28	N.W.	+86	+13	−52 17		Table very unsteady, heavy W. swell.
			N.	−53 53	N.W.					
			S.	−54 08	N.W.					
			N.S.	−54 13	N.W.					
8.	−20 46	87 59	Direct.	−52 28	N.W. by W.	+82	+13	−51 06	−50 57	Table steady. Observer Mr. Burdon, R.N.
			N.	−53 03	N.W. by W.					
			S.	−52 58	N.W. by W.					
			N.S.	−52 13	N.W. by W.					
			Direct.	−52 13	N.W. by W.	+82	+13	−50 48		Table steady.
			N.	−52 33	N.W. by W.					
			S.	−52 30	N.W. by W.					
			N.S.	−52 15	N.W. by W.					
9.	−20 38	85 26	Direct.	−52 03	W. ½ N.	+56	+13	−51 14		Table very unsteady, heavy swell.
			N.	−52 35	W. ½ N.					
			S.	−52 15	W. ½ N.					
			N.S.	−52 38	W. ½ N.					
10.	−20 26	82 22	Direct.	−52 43	W. ½ N.	+56	+13	−51 40	−51 39	Table very unsteady.
			N.	−53 00	W. ½ N.					
			S.	−52 58	W. ½ N.					
			N.S.	−52 33	W. ½ N.					
			Direct.	−52 49	W. ¼ N.	+53	+13	−51 37		Table very unsteady. Observer Mr. Burdon, R.N.
			N.	−52 47	W. ¼ N.					
			S.	−52 25	W. ¼ N.					
			N.S.	−52 50	W. ¼ N.					
11.	−20 36	79 22	Direct.	−52 43	W. ¼ N.	+53	+13	−51 55		Table very unsteady. Observer Mr. Burdon, R.N.
			N.	−52 45	W. ¼ N.					
			S.	−53 05	W. ¼ N.					
			N.S.	−53 30	W. ¼ N.					
			Direct.	−52 38	W. ¼ N.	+53	+13	−51 44		Table unsteady.
			N.	−52 40	W. ¼ N.					
			S.	−53 08	W. ¼ N.					
			N.S.	−52 53	W. ¼ N.					
12.	−20 44	78 31	Direct.	−54 08	W.	+51	+24	−52 47	−52 03	
			N.S.	−53 55	W.					
			Direct.	−53 38	W.N.W.	+72	+24	−51 55		
			N.S.	−53 23	W.N.W.					
			Direct.	−53 23	N.W.	+86	+24	−51 37		
			N.S.	−53 30	N.W.					
			Direct.	−52 53	N.N.W.	+68	+24	−51 20		
			N.S.	−52 50	N.N.W.					
			Direct.	−52 43	N.	+70	+32	−51 01		

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1845.	° ′	° ′		° ′		′	′	° ′	° ′	
May 12.	−20 44	78 31	Direct.	−53 48	N.N.E.	+68	+24	−51 54	−52 03	To obtain corrections for the ship's attraction. Calm, table very unsteady, considerable rolling motion.
			N.S.	−53 03	N.N.E.					
			Direct.	−52 48	S.	+15	+24	−52 01		
			N.S.	−52 33	S.					
			Direct.	−53 48	S.S.W.	+19	+24	−52 46		
			N.S.	−53 10	S.S.W.					
			Direct.	−53 43	S.W.	+30	+24	−52 29		
			N.S.	−53 03	S W.					
			Direct.	−53 48	W.S.W.	+44	+24	−52 35		
			N.S.	−53 38	W.S.W.					
13.	−20 39	77 43	Direct.	−53 48	W.	+51	+24	−52 42	−51 59	
			N.S.	−54 05	W.					
			Direct.	−53 28	N.W.	+86	+24	−51 30		
			N.S.	−53 13	N.W.					
			Direct.	−52 58	N.	+70	+24	−51 18		
			N.S.	−52 45	N.					
			Direct.	−53 23	N.E.	+86	+24	−51 24		
			N.S.	−53 05	N.E.					
			Direct.	−53 53	E.	+51	+24	−52 27		
			N.S.	−53 30	E.					
			Direct.	−53 48	S.E.	+30	+24	−52 34		
			N.S.	−53 08	S.E.					
14.	−20 29	76 22	Direct.	−53 08	W. ½ N.	+56	+13	−52 13	−52 20	Table very unsteady.
			N.	−53 00	W. ½ N.					
			S.	−53 35	W. ½ N.					
			N.S.	−53 43	W. ½ N.					
			Direct.	−53 38	W. ½ N.	+56	+13	−52 27		Table very unsteady. Observer Mr. Burdon, R.N.
			N.	−53 48	W. ½ N.					
			S.	−53 50	W. ½ N.					
			N.S.	−53 08	W. ½ N.					
16.	−20 28	70 46	Direct.	−54 08	W. ¼ N.	+53	+13	−52 51		Table steady.
			N.	−53 48	W. ¼ N.					
			S.	−53 53	W. ¼ N.					
			N.S.	−53 58	W. ¼ N.					
18.	−21 06	68 12	Direct.	−54 43	W.S.W.	+44	+13	−53 10		Table very unsteady.
			N.	−53 45	W.S.W.					
			S.	−54 05	W.S.W.					
			N.S.	−53 53	W.S.W.					
19.	−21 11	67 54	Direct.	−54 28	N.W. by N.	+77	+13	−52 54	−53 02	Table steady, nearly calm.
			N.	−54 35	N.W. by N.					
			S.	−54 23	N.W. by N.					
			N.S.	−54 08	N.W. by N.					
			Direct.	−54 53	N.W. by N.	+77	+13	−53 10		2 P.M. Table steady. Observer Mr. Burdon, R.N.
			N.	−54 45	N.W. by N.					
			S.	−54 38	N.W. by N.					
			N.S.	−54 23	N.W. by N.					
20.	−21 12	67 29	Direct.	−55 03	W. by N.	+63	+13	−53 46	−53 39	Table steady.
			N.	−54 58	W. by N.					
			S.	−55 08	W. by N.					
			N.S.	−54 58	W. by N.					
			Direct.	−54 58	W. by N.	+63	+13	−53 32		Table steady. Observer Mr. Burdon, R.N.
			N.	−54 45	W. by N.					
			S.	−55 00	W. by N.					
			N.S.	−54 28	W. by N.					

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1845.	° ′	° ′		° ′		′	′	° ′	
May 21.	−21 02	66 02	Direct.	−55 28	w. by n.	+63	+13	−54 03	Table steady.
			N.	−55 13	w. by n.				
			S.	−55 23	w. by n.				
			N.S.	−55 13	w. by n.				
23.	−20 31	59 42	Direct.	−55 28	w. by n.	+63	+13	−53 59	Table very unsteady.
			N.	−55 00	w. by n.				
			S.	−55 23	w. by n.				
			N.S.	−55 07	w. by n.				
27.	−20 09	57 31	Direct.	−54 27	Observed on shore.	......	+13	−54 14	Observed by Lieut. Moore, R.N.
	Port Louis, Mauritius.		N.	−54 22					
			S.	−54 59					
			N.S.	−54 01					
30.	−21 44	53 34	Direct.	−55 33	w.s.w. ½ w.	+38	+13	−54 38	Table very unsteady, heavy swell.
			N.	−55 20	w.s.w. ½ w.				
			S.	−55 28	w.s.w. ½ w.				
			N.S.	−55 35	w.s.w. ½ w.				
June 2.	−26 25	49 12	Direct.	−60 33	n.w. by w.	+80	+13	−58 36	Table very unsteady, heavy swell.
			N.	−59 50	n.w. by w.				
			S.	−60 05	n.w. by w.				
			N.S.	−60 10	n.w. by w.				
4.	−27 12	46 09	Direct.	−59 48	w. by s.	+46	+13	−58 44	Table unsteady, fresh breeze.
			N.	−59 18	w. by s.				
			S.	−59 48	w. by s.				
			N.S.	−59 58	w. by s.				
5.	−28 24	43 00	Direct.	−59 43	w.	+51	+13	−58 52	Table very unsteady, fresh breeze.
			N.	−59 53	w.				
			S.	−60 18	w.				
			N.S.	−59 48	w.				
6.	−28 44	42 01	Direct.	−60 33	w.n.w.	+72	+13	−59 01	Table very unsteady, fresh breeze.
			N.	−60 25	w.n.w.				
			S.	−60 23	w.n.w.				
			N.S.	−60 23	w.n.w.				
7.	−28 35	40 24	Direct.	−59 58	w. ½ n.	+56	+13	−58 54	Table very unsteady.
			N.	−59 56	w. ½ n.				
			S.	−60 28	w. ½ n.				
			N.S.	−59 50	w. ½ n.				
8.	−28 57	37 52	Direct.	−60 38	w.	+51	+13	−59 08	Table steady, nearly a calm.
			N.	−59 45	w.				
			S.	−60 25	w.				
			N.S.	−60 02	w.				
12.	−30 33	33 19	Direct.	−59 03	w.n.w.	+72	+13	−57 19	Table unsteady.
			N.	−58 30	w.n.w.				
			S.	−58 43	w.n.w.				
			N.S.	−58 38	w.n.w.				
13.	−31 06	31 34	Direct.	−58 33	w. by s. ½ s.	+42	+13	−57 28	Table steady, nearly a calm.
			N.	−58 20	w. by s. ½ s.				
			S.	−58 35	w. by s. ½ s.				
			N.S.	−58 05	w. by s. ½ s.				
14.	−33 01	29 36	Direct.	−58 38	w.	+51	+13	−57 34	Table unsteady, fresh breeze.
			N.	−58 25	w.				
			S.	−59 08	w.				
			N.S.	−58 20	w.				
15.	−34 31	27 04	Direct.	−58 23	w. ½ n.	+56	+13	−57 06	Table very unsteady long heavy swell.
			N.	−58 08	w. ½ n.				
			S.	−58 45	w. ½ n.				
			N.S.	−57 45	w. ½ n.				

Observations of Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.		Remarks.
						Ship's attraction.	Index.			
1835.	° ′	° ′		° ′		′	′	° ′	° ′	
June 16.	−35 46	23 35	Direct.	−57 38	W. by N.	+63	+13	−56 08		Table steady, fresh breeze.
			N.	−57 23	W. by N.					
			S.	−57 15	W. by N.					
			N.S.	−57 20	W. by N.					
17.	−35 36	21 40	Direct.	−56 48	W. by N.	+72	+13	−55 18		Table steady.
			N.	−56 43	W. by N.					
			S.	−56 40	W. by N.					
			N.S.	−56 40	W. by N.					
18.	−35 07	20 46	Direct.	−56 18	W. by S.	+46	+13	+55 08		Table steady.
			N.	−55 45	W. by S.					
			S.	−56 08	W. by S.					
			N.S.	−56 18	W. by S.					
23.	−34 12	18 26	Direct.	−54 17	Observed on shore.	.....	+24	−53 37	−53 37	Observed in the dockyard at Simon's Bay.
			N.S.	−53 45						
30.	−33 56	18 29	Direct.	−54 12	Observed on shore.	......	+13	−53 32	−53 34	Monthly mean dip by Robinson's needles A 1 53° 24′ A 2 53 24 Mean 53 24
			N.	−53 13						
			S.	−53 46						
			N.S.	−53 51						
July 2.	Magnetic Observatory, Cape of Good Hope.		Direct.	−54 08	Observed on shore.	......	+13	−53 30		
			N.	−53 15						
			S.	−53 46						
			N.S.	−53 44						
June 23.	−34 12	18 26	Direct.	−53 59	S.	+09	+24	−53 20	−53 28	To obtain corrections for the ship's attraction.
	At anchor in Simon's Bay, Cape of Good Hope.		N.S.	−53 46	S.					
			Direct.	−53 50	S.S.W.	+14	+24	−52 56		
			N.S.	−53 17	S.S.W.					
			Direct.	−54 25	S.W.	+26	+24	−53 20		
			N.S	−53 54	S.W.					
			Direct.	−55 04	W.S.W.	+41	+24	−53 50		
			N.S.	−54 46	W.S.W.					
			Direct.	−55 18	W.	+51	+24	−53 54		
			N.S.	−55 01	W.					
			Direct.	−55 34	W.N.W.	+72	+24	−53 36		
			N.S.	−54 49	W.N.W.					
			Direct.	−55 30	N.W.	+88	+24	−53 28		
			N.S.	−55 10	N.W.					
			Direct.	−55 07	N.N.W.	+71	+24	−53 25		
			N.S.	−54 52	N.N.W.					
			Direct.	−54 36	N.	+75	+24	−52 46		
			N.S.	−54 14	N.					
			Direct.	−55 10	N.N.E.	+71	+24	−53 14		
			N.S.	−54 28	N.N.E.					
			Direct.	−55 16	N.E.	+87	+24	−53 10		
			N.S.	−54 46	N.E.					
			Direct.	−55 34	E.N.E.	+72	+24	−53 41		
			N.S.	−54 59	E.N.E.					
			Direct.	−55 22	E.	+51	+24	−53 55		
			N.S.	−54 58	E.					
			Direct.	−55 05	E.S.E.	+41	+24	−53 43		
			N.S.	−54 31	E.S.E.					
			Direct.	−54 24	S.E.	+26	+24	−53 26		
			N.S.	−54 07	S.E.					
			Direct.	−54 39	S.S.E.	+14	+24	−53 37		
			N.S.	−53 50	S.S.E.					

Observations of the Magnetic Force made on board Her Majesty's hired Bark "Pagoda," from the 10th of January 1845 to the 20th of June 1845, with Needle A. of C. 9. one hour after Noon.

Observer, Lieut. T. E. L. Moore, R.N.

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Jan. 10.	−34° 46′	17° 46′	Def. N.	48° 19′	64°	w. by n.	0·988	—·008	·000	0·980	·985	Fresh breezes, a head swell.
			Def. S.	49 15	64	w. by n.	0·975	—·008	·000	0·967		
			Def. N.S.	67 36	64	w. by n.	0·988	—·008	—·001	0·979		
			Def. N.	46 11	64	w. by n.	1·001	—·008	·000	0·993		
			Def. S.	45 42	64	w. by n.	1·014	—·008	·000	1·006		
11.	−35 09	15 09	Def. N.	49 23	68	n.w. by w.	0·960	+·002	—·001	0·961	·968	A little motion.
			Def. S.	49 22	68	n.w. by w.	0·973	+·002	—·001	0·974		
			Def. N.S.	68 57	68	n.w. by w.	0·956	+·002	—·002	0·956		
			Mag. N.	47 00	66	n.w. by w.	0·969	+·002	—·001	0·970		
			Mag. S.	46 54	66	n.w. by w.	0·966	+·002	—·001	0·967		
			wt. 1 gr.	19 56	66	n.w. by w.	0·922	+·002	+·001	0·925*		
			wt. 2 grs.	42 14	66	n.w. by w.	0·978	+·002	+·001	0·981		
12.	−35 17	14 00	Def. N.	49 55	78	w. ½ s.	0·950	—·016	—·001	0·933	·923	A little motion.
			Def. S.	50 42	78	w. ½ s.	0·929	—·016	—·001	0·912		
			Def. N.S.	69 27	78	w. ½ s.	0·944	—·016	—·005	0·923		
			Mag. N.	48 03	78	w. ½ s.	0·930	—·016	—·001	0·913		
			Mag. S.	47 16	78	w. ½ s.	0·952	—·016	—·001	0·935		
13.	−35 24	13 23	Mag. N.	48 59	72	s.w. ½ s.	0·971	—·033	—·001	0·937	·933	A little motion.
			Mag. S.	50 00	72	s.w. ½ s.	0·952	—·033	—·001	0·918		
			Mag. N.S.	68 30	72	s.w. ½ s.	0·965	—·033	—·003	0·929		
			Mag. N.	47 13	72	s.w. ½ s.	0·961	—·033	—·001	0·927		
			Mag. S.	46 58	72	s.w. ½ s.	0·966	—·033	—·001	0·932		
			wt. 1 gr.	19 17	72	s.w. ½ s.	0·952	—·033	+·001	0·920*		
			wt. 1½ gr.	30 42	76	s.w. ½ s.	0·981	—·033	+·001	0·949		
			wt. 2 grs.	42 46	76	s.w. ½ s.	0·968	—·033	+·001	0·936		
15.	−38 42	14 27	Def. N.	47 18	64	s. by w. ½ w.	1·019	—·038	·000	0·981	·978	Table unsteady, a head swell.
			Def. S.	48 25	64	s. by w. ½ w.	1·005	—·038	·000	0·967		
			Def. N.S.	66 52	64	s. by w. ½ w.	1·006	—·038	—·001	0·967		
			Mag. N.	45 49	64	s. by w. ½ w.	1·018	—·038	·000	0·980		
			Mag. S.	45 21	64	s. by w. ½ w.	1·031	—·038	·000	0·993		
16.	−39 10	14 38	Def N.	48 27	70	s.w.by w.½ w.	0·984	—·024	—·001	0·959	·964	Table very unsteady.
			Def. S.	48 53	70	s.w.by w.½ w.	0·988	—·024	—·001	0·963		
			Def. N.S.	67 27	70	s.w.by w.½ w.	0·992	—·024	—·003	0·965		
			Mag. N.	46 37	70	s.w.by w.½ w.	0·985	—·024	—·001	0·960		
			Mag. S.	46 04	70	s.w.by w.½ w.	0·997	—·024	—·001	0·972		
17.	−40 41	14 16	Mag. N.	47 52	68	w.s.w.	1·000	—·024	—·001	0·975	·984	A heavy head swell, much motion.
			Mag. S.	48 16	68	w.s.w.	1·009	—·024	—·001	0·984		
			Mag. N.S.	66 22	68	w.s.w.	1·020	—·024	—·002	0·994		
21.	−50 21	10 31	Mag. N.	45 42	45	s.w.	1·074	—·032	+·001	1·043	1·051	Moderate breezes, a little motion.
			Mag. S.	46 14	45	s.w.	1·076	—·032	+·001	1·045		
			Mag. N.S.	63 54	45	s.w.	1·086	—·032	+·004	1·058		
			Mag. N.	44 19	45	s.w.	1·082	—·032	+·001	1·051		
			Mag. S.	44 07	45	s.w.	1·090	—·032	+·001	1·059		
23.	−50 48	10 18	Mag. N.	44 45	43	s.w.by w.½ w.	1·110	—·024	+·001	1·087	1·093	
			Mag. S.	44 54	43	s.w.by w.½ w.	1·120	—·024	+·001	1·097		
			Mag. N.S.	62 39	43	s.w.by w.½ w.	1·125	—·024	+·005	1·106		
			Mag. N.	43 44	42	s.w.by w.½ w.	1·108	—·024	+·001	1·085		
			Mag. S.	43 43	42	s.w.by w.½ w.	1·112	—·024	+·001	1·089		
24.	−51 44	9 36	Mag. N.	44 15	49	s.w. by w.	1·128	—·024	+·001	1·105	1·109	Moderate breezes, table steady. P.M. A head swell, much motion.
	−51 56	9 30	Mag. N.S.	62 19	50	s.w.by w.½ w.	1·136	—·024	+·003	1·115		
			wt. 1 gr.	17 12	50	s.w.by w.½ w.	1·063	—·024	—·001	1·038*		
			wt. 2 grs.	35 29	50	s.w.by w.½ w.	1·132	—·024	—·001	1·107		

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Jan. 25.	−53° 21'	7° 32'	Def. N.	43° 49'	41°	s.w.by w.½w.	1·145	—·024	+·001	1·122	1·134	Table steady; passing through streams of ice.
			Def. S.	43 59	41	s.w.by w.½w.	1·152	—·024	+·001	1·129		
			Def. N.S.	61 56	41	s.w.by w.½w.	1·147	—·024	+·006	1·129		
			Mag. N.	42 39	39	s.w.by w.½w.	1·159	—·024	+·002	1·137		
			Mag. S.	42 33	39	s.w.by w.½w.	1·174	—·024	+·002	1·152		
26.	−54 02	6 02	Def. N.	43 43	42	w. by n.	1·148	—·012	+·001	1·137	1·141	Very steady, small pieces of loose ice about the ship.
			Def. S.	44 14	42	w. by n.	1·145	—·012	+·001	1·134		
			Def. N.S.	62 09	42	w. by n.	1·142	—·012	+·006	1·136		
			Mag. N.	43 00	40	w. by n.	1·142	—·012	+·002	1·132		
			Mag. S.	42 44	40	w. by n.	1·164	—·012	+·002	1·154		
			wt. 1 gr.	16 40	40	w. by n.	1·096	—·012	+·002	1·086*		
			wt. 2 grs.	34 23	40	w. by n.	1·164	—·012	+·002	1·154		
27.	−55 18	5 55	Def. N.	42 50	39	s.s.w. ½ w.	1·184	—·042	+·001	1·143	1·143	Ship pitching heavily, fresh breezes.
31.	−61 14	9 07	Def. N.	39 38	37	s.s.e.	1·324	—·042	+·002	1·284	1·288	Table steady, heavy snow, passing various icebergs.
			Def. S.	40 08	37	s.s.e.	1·320	—·042	+·002	1·280		
			Def. N.S.	57 04	37	s.s.e.	1·331	—·042	+·008	1·297		
			Mag. N.	39 45	37	s.s.e.	1·310	—·042	+·003	1·271		
			Mag. S.	39 30	37	s.s.e.	1·349	—·042	+·003	1·310		
Feb. 1.	−62 06	12 52	Def. N.	38 10	37	s.e. by s.	1·398	—·040	+·002	1·360	1·349	Much motion, table unsteady.
			Def. S.	38 58	37	s.e. by. s.	1·376	—·040	+·002	1·338		
2.	−61 56	16 36	Def. N.	39 17	37	s.e. ½ e.	1·341	—·036	+·002	1·307	1·321	Heavy snow, a head sea, ship pitching violently.
			Def. S.	39 21	36	s.e. ½ e.	1·357	—·036	+·002	1·323		
			Def. N.S.	56 28	36	s.e. ½ e.	1·358	—·036	+·009	1·331		
			Mag. N.	39 21	36	s.e. ½ e.	1·339	—·036	+·003	1·306		
			Mag. S.	39 08	35	s.e. ½ e.	1·372	—·036	+·003	1·339		
4.	−63 00	20 40	Def. N.	38 17	39	s. ½ e.	1·391	—·051	+·001	1·341	1·347	Water very clear from ice, a little motion. Vibration great.
			Def. S.	38 35	39	s. ½ e.	1·395	—·051	+·001	1·345		
			Def. N.S.	56 04	39	s. ½ e.	1·376	—·051	+·008	1·333		
			Mag. N.	38 17	39	s. ½ e.	1·406	—·051	+·002	1·357		
			Mag. S.	38 35	39	s. ½ e.	1·405	—·051	+·002	1·356		
			wt. 1 gr.	13 26	39	s. ½ e.	1·353	—·051	—·002	1·300*		
			wt. 2 grs.	27 58	39	s. ½ e.	1·402	—·051	—·002	1·349		
5.	−63 19	21 48	Def. N.	38 36	37	s.s.e.	1·376	—·046	+·002	1·332	1·362	A heavy swell from S.E., light breezes, table steady.
			Def. S.	38 24	37	s.s.e.	1·405	—·046	+·002	1·361		
			Def. N.S.	55 38	37	s.s.e.	1·397	—·046	+·009	1·360		
			Mag. N.	38 27	36	s.s.e.	1·396	—·046	+·003	1·353		
			Mag. S.	38 38	36	s.s.e.	1·407	—·046	+·003	1·364		
			wt. 1 gr.	13 51	36	s.s.e.	1·313	—·046	—·003	1·264*		
			wt. 2 grs.	26 57	34	s.s.e.	1·450	—·046	—·003	1·401		
6.	−64 25	24 18	Def. N.	37 17	39	s.s.e. ½ e.	1·447	—·045	+·001	1·403	1·398	Water perfectly smooth, very steady.
			Def. S.	37 48	39	s.s.e. ½ e.	1·436	—·045	+·001	1·392		
			Def. N.S.	54 51	39	s.s.e. ½ e.	1·436	—·045	+·008	1·399		
7.	−65 39	28 48	Def. N.	36 34	41	s. by e. ½ e.	1·487	—·051	+·001	1·437	1·432	Table steady, water smooth, no ice in sight.
			Def. S.	37 11	41	s. by e. ½ e.	1·472	—·051	+·001	1·422		
			Def. N.S.	54 15	41	s. by e. ½ e.	1·466	—·051	+·008	1·423		
			Mag. N.	37 00	41	s. by e. ½ e.	1·499	—·051	+·002	1·450		
			Mag. S.	37 20	41	s. by e. ½ e.	1·487	—·051	+·002	1·438		
			wt. 1 gr.	13 03	39	s.s.e.	1·392	—·050	—·002	1·340*		
			wt. 2 grs.	26 28	39	s.s.e.	1·475	—·050	—·002	1·423		
8.	−66 27	30 45	Def. N.	36 27	34	s.e. by e.	1·494	—·042	+·002	1·454	1·448	Fresh breeze, table unsteady.
			Def. S.	36 58	34	s.e. by e.	1·483	—·042	+·002	1·443		
			Def. N.S.	54 05	33	s.e. by e.	1·474	—·042	+·011	1·443		
			Mag. N.	37 00	30	s.e. by e.	1·499	—·042	+·004	1·461		
			Mag. S.	37 32	30	s.e. by e.	1·475	—·042	+·004	1·437		

* Omitted in mean.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Feb. 9.	−66° 36′	36° 50′	Def. N.	36° 06′	39°	S.E. by E.	1·514	—·042	+·001	1·473	1·470	Light breeze, very steady, water smooth.
			Def. S.	36 43	39	S.E. by E.	1·508	—·042	+·001	1·467		
			Def. N.S.	53 41	36	S.E. by E.	1·505	—·042	+·010	1·473		
			Mag. N.	36 55	35	S.E. by E.	1·505	—·042	+·003	1·466		
			Mag. S.	36 59	34	S.E. by E.	1·509	—·042	+·003	1·470		
10.	−67 11	38 51	Def. N.	35 39	34	S. by W.	1·540	—·050	+·002	1·492	1·483	Steady, water very smooth.
			Def. S.	36 31	34	S. by W.	1·509	—·050	+·002	1·461		
			Def. N.S.	52 45	34	S. by W.	1·549	—·050	+·009	1·508		
			Mag. N.	36 27	34	S. by W.	1·540	—·050	+·003	1·493		
			Mag. S.	37 02	34	S. by W.	1·509	—·050	+·003	1·462		
11.	−67 39	40 28	Def. N.	36 10	35	N.E.	1·510	—·016	+·002	1·496	1·496	Sailing along a pack of ice, unsteady.
12.	−67 18	40 22	Def. N.	35 30	32	S. ½ E.	1·548	—·050	+·003	1·501	1·496	Fresh breeze, table unsteady.
			Def. S.	36 07	32	S. ½ E.	1·533	—·050	+·003	1·486		
			Def. N.S.	53 16	32	S. ½ E.	1·520	—·050	+·013	1·483		
			Mag. N.	36 37	32	S. ½ E.	1·529	—·050	+·004	1·483		
			Mag. S.	36 03	32	S. ½ E.	1·575	—·050	+·004	1·529		
13.	−66 55	14 16	Def. N.	36 00	34	E.N.E.	1·519	—·025	+·002	1·496	1·490	Swell from E., table unsteady.
			Def. S.	36 37	34	E.N.E.	1·504	—·025	+·002	1·481		
			Def. N.S.	53 29	33	E.N.E.	1·506	—·025	+·011	1·492		
			Mag. N.	36 43	33	E.N.E.	1·521	—·025	+·004	1·500		
			Mag. S.	37 06	33	E.N.E.	1·503	—·025	+·004	1·482		
14.	−66 24	40 01	Def. N.	36 18	34	N.E. by N.	1·502	—·016	+·002	1·488	1·494	Table unsteady, very squally.
			Def. S.	36 24	34	N.E. by N.	1·515	—·016	+·002	1·501		
16.	−64 52	38 37	Def. N.	35 59	41	S. by E.	1·520	—·050	+·001	1·471	1·450	Thick weather, a heavy swell, unsteady.
			Def. S.	36 56	41	S. by E.	1·487	—·050	+·001	1·438		
			Def. N.S.	53 48	41	S. by E.	1·490	—·050	+·008	1·448		
			Mag. N.	37 07	40	S. by E.	1·493	—·050	+·003	1·446		
			Mag. S.	37 15	40	S. by E.	1·492	—·050	+·003	1·445		
17.	−66 43	40 12	Def. N.	36 34	36	N.	1·487	—·018	+·002	1·471	1·482	Calm, a heavy sea, not steady.
			Def. S.	37 08	36	N.	1·475	—·018	+·002	1·459		
			Def. N.S.	53 18	38	N.	1·518	—·018	+·010	1·510		
			Mag. N.	36 53	38	N.	1·505	—·018	+·003	1·490		
			Mag. S.	37 13	37	N.	1·495	—·018	+·003	1·480		
19.	−64 05	41 09	Def. N.	36 35	37	E. by S.	1·486	—·035	+·002	1·453	1·453	Very unsteady, a swell from N.
20.	−63 19	45 52	Def. N.	36 12	45	S.E. by E. ½ E.	1·507	—·040	+·001	1·468	1·462	A heavy swell, strong breeze, with a heavy sea running.
			Def. S.	37 10	46	S.E. by E. ½ E.	1·474	—·040	+·001	1·435		
			Def. N.S.	53 40	46	S.E. by E. ½ E.	1·497	—·040	+·006	1·463		
	−63 22	45 58	Def. N.	36 08	44	S.E.	1·511	—·046	+·001	1·466		
			Def. S.	36 33	42	S.E.	1·507	—·046	+·001	1·462		
			Def. N.S.	53 22	39	S.E.	1·514	—·046	+·009	1·477		
21.	−63 36	46 46	Def. N.	36 00	40	S.E.	1·519	—·046	+·001	1·474	1·470	Table unsteady, much motion.
			Def. S.	36 33	39	S.E.	1·507	—·046	+·001	1·462		
			Def. N.S.	53 23	39	S.E.	1·513	—·046	+·009	1·476		
	−63 36	46 50	Def. N.	36 01	40	S.E.	1·518	—·046	+·001	1·473		
			Def. S.	36 37	40	S.E.	1·505	—·046	+·001	1·460		
			Def. N.S.	53 26	39	S.E.	1·511	—·046	+·009	1·474		
			Mag. N.	36 39	39	S.E.	1·525	—·046	+·003	1·482		
			Mag. S.	37 09	39	S.E.	1·500	—·046	+·003	1·457		
25.	−61 34	53 49	Def. N.	35 41	42	S.E. ½ E.	1·537	—·044	+·001	1·494	1·498	Fresh breeze, table steady.
			Def. S.	36 13	42	S.E. ½ E.	1·527	—·044	+·001	1·484		
			Def. N.S.	53 21	40	S.E. ½ E.	1·515	—·044	+·009	1·480		
			Mag. N.	36 14	39	S.E. ½ E.	1·558	—·044	+·003	1·517		
			Mag. S.	36 19	39	S.E. ½ E.	1·557	—·044	+·003	1·516		

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Feb. 26.	−61° 29′	57° 33′	Def. N.	35° 11′	40°	S.E. ½ E.	1·566	−·044	+·001	1·523		
			Def. S.	35 46	40	S.E. ½ E.	1·552	−·044	+·001	1·509		
			Def. N.S.	52 55	40	S.E. ½ E.	1·541	−·044	+·009	1·506		
	−61 22	57 41	Def. N.	35 07	40	S.E.	1·571	−·046	+·001	1·526		
			Def. S.	35 57	40	S.E.	1·540	−·046	+·001	1·495		
			Def. N.S.	52 58	40	S.E.	1·540	−·046	+·009	1·503	1·506	Fresh breezes, table steady.
			Mag. N.	36 24	39	S.E.	1·543	−·046	+·003	1·500		
			Mag. S.	36 22	38	S.E.	1·553	−·046	+·003	1·510		
			wt. 1 gr.	12 41	38	S.E.	1·432	−·046	−·003	1·383*		
			wt. 2 grs.	25 29	38	S.E.	1·528	−·046	−·003	1·479		
27.	−61 10	64 20	Def. N.	34 35	39	S.S.E. ½ E.	1·602	−·048	+·002	1·556	1·560	Very unsteady.
			Def. S.	34 49	39	S.S.E. ½ E.	1·610	−·048	+·002	1·564		
28.	−61 49	71 30	Def. N.	33 47	38	S.S.E.	1·651	−·049	+·002	1.604		
			Def. S.	34 15	38	S.S.E.	1·644	−·049	+·002	1·597		Very unsteady.
			Def. N.S.	51 17	37	S.S.E.	1·635	−·049	+·010	1·596		
			Mag. N.	34 35	37	S.S.E.	1·680	−·049	+·003	1·634		
			Mag. S.	35 15	35	S.S.E.	1·637	−·049	+·003	1·591	1·605	Table steady.
	−61 49	71 32	Def. N.	33 26	35	S.S.E.	1·675	−·049	+·002	1·628		
			Def. S.	34 27	35	S.S.E.	1·632	−·049	+·002	1·585		
			Def. N.S.	51 05	35	S.S.E.	1·646	−·049	+·011	1·608		
Mar. 1.	−62 10	72 25	Def. N.	33 14	46	S.E. by S.	1·687	−·047	+·002	1·642		
			Def. S.	33 31	46	S.E. by S.	1·692	−·047	+·002	1·647		
			Def. N.S.	50 33	46	S.E. by S.	1·680	−·047	+·006	1·639		
			Mag. N.	34 24	46	S.E. by S.	1·695	−·047	+·002	1·650	1·642	Calm, table steady.
			Mag. S.	34 49	46	S.E. by S.	1·673	−·047	+·002	1·628		
			wt. 1 gr.	10 37	46	S.E. by S.	1·706	−·047	−·002	1·657*		
			wt. 2 grs.	22 49	46	S.E. by S.	1·695	−·047	−·002	1·646		
2.	−62 47	76 14	Def. N.	33 15	42	S.E. by E. ½ E.	1·687	−·047	+·001	1·641		
			Def. S.	33 30	42	S.E. by E. ½ E.	1·693	−·041	+·001	1·653		
			Def. N.S.	50 26	42	S.E. by E. ½ E.	1·686	−·041	+·008	1·653		
			Mag. N.	34 15	42	S.E. by E. ½ E.	1·706	−·041	+·003	1·668		
			Mag. S.	34 40	42	S.E. by E. ½ E.	1·685	−·041	+·003	1·647		
			wt. 1 gr.	11 02	42	S.E. by E. ½ E.	1·643	−·041	−·003	1·599*	1·653	Steady breeze. table steady.
			wt. 2 grs.	22 31	42	S.E. by E. ½ E.	1·716	−·041	−·003	1·672		
	−62 49	76 16	Def. N.	32 46	42	S.	1·717	−·056	+·002	1·663		
			Def. S.	33 30	42	S.	1·693	−·056	+·002	1·639		
			Def. N.S.	50 24	42	S.	1·688	−·056	+·008	1·640		
3.	−64 20	79 38	Def. N.	32 32	34	S. by W. ½ W.	1·732	−·054	+·003	1·681		
			Def. S.	32 58	32	S. by W. ½ W.	1·728	−·054	+·003	1·677	1·678	Fresh breeze, unsteady, thick, with squalls of snow.
			Def. N.S.	49 56	31	S. by W. ½ W.	1·717	−·054	+·014	1·677		
5.	−61 42	85 07	Def. N.	31 35	36	S.E. ½ E.	1·795	−·049	+·002	1·748		
			Def. S.	32 09	37	S.E. ½ E.	1·783	−·049	+·002	1·736	1·730	Unsteady; aurora visible.
			Def. N.S.	49 35	37	S.E. ½ E.	1·742	−·049	+·012	1·705		
6.	−60 48	88 33	Def. N.	31 34	39	S.E.	1·796	−·051	+·002	1·747		
			Def. S.	32 27	39	S.E.	1·762	−·051	+·002	1·713		
			Def. N.S.	49 32	38	S.E.	1·746	−·051	+·011	1·706	1·747	Very unsteady, with thick weather.
			Mag. N.	32 38	37	S.E.	1·833	−·051	+·004	1·786		
			Mag. S.	33 01	37	S.E.	1·830	−·051	+·004	1·783		
7.	−61 23	91 15	Def. N.	31 46	41	S.S.W.	1·783	−·053	+·002	1·732		
			Def. S.	32 14	42	S.S.W.	1·779	−·053	+·002	1·728		
			Def. N.S.	49 00	42	S.S.W.	1·785	−·053	+·009	1·741	1·749	Unsteady.
			Mag. N.	32 54	42	S.S.W.	1·811	−·053	+·003	1·761		
			Mag. S.	32 57	42	S.S.W.	1·834	−·053	+·003	1·784		

* Omitted in mean.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Mar. 8.	−61° 07′	92° 10′	Def. N.	31° 13′	41°	E.S.E.	1·824	—·046	+·002	1·780	1·758	Unsteady, with snow.
			Def. S.	32 04	40	E.S.E.	1·790	—·046	+·002	1·746		
			Def. N.S.	49 04	38	E.S.E.	1·782	—·046	+·011	1·747		
9.	−60 30	92 34	Def. N.	31 19	40	S.E. by E.	1·817	—·048	+·002	1·771	1·750	Very unsteady.
			Def. S.	32 09	41	S.E. by E.	1·784	—·048	+·002	1·738		
			Def. N.S.	49 08	41	S.E. by E.	1·780	—·048	+·010	1·742		
10.	−60 03	96 03	Def. N.	31 08	39	E.S.E.	1·832	—·046	+·002	1·788	1·770	Aurora visible, table steady.
			Def. S.	31 56	38	E.S.E.	1·796	—·046	+·002	1·752		
11.	−59 45	99 50	Def. N.	29 54	35	E. ½ N.	1·919	—·041	+·002	1·880	1·836	A heavy sea, very unsteady.
			Def. S.	30 31	34	E. ½ N.	1·908	—·041	+·002	1·869		
			Def. N.S.	48 58	34	E. ½ N.	1·788	—·041	+·013	1·760		
			Mag. N.	32 21	34	E. ½ N.	1·855	—·041	+·004	1·818		
			Mag. S.	32 23	34	E. ½ N.	1·888	—·041	+·004	1·851		
13.	−57 46	99 17	Def. N.	30 34	46	E.N.E.	1·870	—·039	+·001	1·832	1·813	Very unsteady.
			Def. S.	31 28	46	E.N.E.	1·831	—·039	+·001	1·793		
14.	−56 56	101 36	Def. N.	30 31	40	E. by S.	1·876	—·047	+·002	1·831	1·802	A.M. Aurora visible, unsteady.
			Def. S.	31 20	41	E. by S.	1·842	—·047	+·002	1·797		
			Def. N.S.	48 35	41	E. by S.	1·816	—·047	+·010	1·779		
15.	−55 40	103 18	Def. N.	30 30	41	E.N.E.	1·876	—·039	+·002	1·839	1·815	Squally with snow, unsteady.
			Def. S.	31 10	41	E.N.E.	1·854	—·039	+·002	1·817		
			Def. N.S.	48 34	41	E.N.E.	1·817	—·039	+·010	1·788		
16.	−54 38	106 15	Def. N.	30 03	39	E.	1·909	—·045	+·002	1·866	1·817	Heavy squalls, unsteady, snow.
			Def. S.	31 18	38	E.	1·844	—·045	+·002	1·801		
			Def. N.S.	48 34	38	E.	1·817	—·045	+·012	1·784		
17.	−54 10	108 15	Def. N.	29 59	39	E. by S.	1·913	—·047	+·002	1·868	1·821	A strong gale, very unsteady.
			Def. S.	31 05	40	E. by S.	1·860	—·047	+·002	1·815		
			Def. N.S.	48 34	40	E. by S.	1·817	—·047	+·011	1·781		
18.	−53 00	110 30	Def. N.	30 28	44	N.E.	1·878	—·036	+·002	1·844	1·825	Unsteady, a heavy swell from westward, strong breeze.
			Def. S.	31 14	44	N.E.	1·849	—·036	+·002	1·815		
			Def. N.S.	48 30	43	N.E.	1·822	—·036	+·009	1·795		
			Mag. N.	31 55	43	N.E.	1·889	—·036	+·003	1·856		
			Mag. S.	32 48	43	N.E.	1·850	—·036	+·003	1·817		
20.	−48 57	112 56	Def. N.	30 52	47	N.E. ½ N.	1·849	—·035	+·001	1·815	1·821	Fresh breeze, very unsteady.
			Def. S.	31 26	48	N.E. ½ N.	1·834	—·035	+·001	1·800		
			Def. N.S.	48 22	48	N.E. ½ N.	1·831	—·035	+·006	1·802		
			Mag. N.	32 20	49	N.E. ½ N.	1·857	—·035	+·002	1·824		
			Mag. S.	32 58	49	N.E. ½ N.	1·835	—·035	+·002	1·802		
			wt. 1 gr.	9 59	50	N.E. ½ N.	1·813	—·035	—·002	1·776*		
			wt. 2 grs.	20 01	50	N.E. ½ N.	1·920	—·035	—·002	1·883		
			wt. 3 grs.	31 32	50	N.E. ½ N.	1·859	—·035	—·002	1·822		
22.	−47 21	115 15	Def. N.	30 38	50	N.W. ½ N.	1·866	—·029	+·001	1·838	1·842	Light breeze, table steady, thick fog.
			Def. S.	30 34	50	N.W. ½ N.	1·897	—·029	+·001	1·869		
			Def. N.S.	48 29	50	N.W. ½ N.	1·821	—·029	+·005	1·797		
			Mag. N.	32 07	50	N.W. ½ N.	1·876	—·029	+·002	1·849		
			Mag. S.	32 26	50	N.W. ½ N.	1·885	—·029	+·002	1·858		
24.	−45 08	116 50	Def. N.	31 01	49	N. by E.	1·840	—·020	+·001	1·821	1·820	A heavy swell from westward, unsteady.
			Def. S.	31 21	50	N. by E.	1·838	—·020	+·001	1·819		
25.	−43 22	116 49	Def. N.	31 06	55	N. ½ E.	1·833	—·020	·000	1·813	1·804	A heavy swell, unsteady.
			Def. S.	31 49	55	N. ½ E.	1·807	—·020	·000	1·787		
			Def. N.S.	48 57	55	N. ½ E.	1·789	—·020	+·002	1·771		
			Mag. N.	32 33	55	N. ½ E.	1·840	—·020	+·001	1·821		
			Mag. S.	33 24	56	N. ½ E.	1·793	—·020	+·001	1·774		
			wt. 1 gr.	10 20	56	N. ½ E.	1·753	—·020	—·001	1·732*		
			wt. 2 grs.	20 30	56	N. ½ E.	1·877	—·020	—·001	1·856		

* Omitted in mean.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections. Ship's attraction.	Corrections. Temperature.	Corrected Intensity.		Remarks.
1845. Mar. 26.	—41° 00′	116° 42′	Def. N.	31° 40′	56°	N. by W.	1·790	—·020	·000	1·770	1·758	A heavy westerly swell.
			Def. S.	31 37	56	N. by W.	1·821	—·020	·000	1·801		
			Def. N.S.	49 41	56	N. by W.	1·736	—·020	+·002	1·718		
			Mag. N.	33 19	56	N. by W.	1·780	—·020	+·001	1·761		
			Mag. S.	33 46	56	N. by W.	1·759	—·020	+·001	1·740		
27.	—38 40	116 15	Def. N.	32 33	62	N. by E.	1·731	—·012	·000	1·719	1·722	Table steady.
			Def. S.	32 35	62	N. by E.	1·752	—·012	·000	1·740		
			Def. N.S.	49 55	62	N. by E.	1·720	—·012	—·001	1·707		
28.	—37 00	116 57	Def. N.	33 12	63	N. by E.	1·689	—·012	·000	1·677	1·677	Unsteady.
			Def. S.	33 34	64	N. by E. ½ E.	1·687	—·012	·000	1·675		
			Def. N.S.	50 42	64	N. by E. ½ E.	1·670	—·012	—·002	1·656		
			Mag. N.	34 06	68	N. by E. ½ E.	1·717	—·012	—·001	1·704		
			Mag. S.	34 41	68	N. by E. ½ E.	1·681	—·012	—·001	1·668		
			wt. 1 gr.	11 08	68	N. by E. ½ E.	1·628	—·012	+·001	1·617*		
			wt. 2 grs.	22 48	68	N. by E. ½ E.	1·696	—·012	+·001	1·685		
			wt. 3 grs.	35 19	65	N. by E. ½ E.	1·682	—·012	+·001	1·671		
29.	—36 11	116 48	Def. N.	33 12	67	N.N.E.	1·689	—·012	—·001	1·676	1·670	Unsteady.
			Def. S.	33 21	67	N.N.E.	1·702	—·012	—·001	1·689		
			Def. N.S.	50 51	68	N.N.E.	1·661	—·012	—·003	1·646		
30.	—35 07	117 38	Def. N.	32 54	66	N.N.E.	1·708	—·012	—·001	1·695	1·694	Unsteady.
			Def. S.	33 13	66	N.N.E.	1·712	—·012	—·001	1·699		
			Def. N.S.	50 12	66	N.N.E.	1·701	—·012	—·002	1·687		
April 7.	—35 02 King George's Sound, West Australia.	117 56	Def. N.	33 11	68	Observed on shore.	1·690	……	—·001	1·689	1·688	On the 8th needle A. was found to have been injured, needle B. was therefore used subsequently.
			Def. S.	33 32	68		1·690	……	—·001	1·689		
			Def. N.S.	50 24	68		1·689	……	—·003	1·686		
			Mag. N.	34 30	68		1·687	……	—·001	1·686		
			Mag. S.	34 34	69		1·691	……	—·001	1·690		
			wt. 1 gr.	10 44	69		1·688	……	+·001	1·689		
			wt. 1½ gr.	17 16	69		1·688	……	+·001	1·689		
			wt. 2 grs.	22 56	69		1·688	……	+·001	1·689		
			wt. 2½ grs.	28 18	69		1·688	……	+·001	1·689		
			wt. 3 grs.	35 11	69		1·688	……	+·001	1·689		

Needle B.

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections. Ship's attraction.	Corrections. Temperature.	Corrected Intensity.		Remarks.
12.	—35 02 King George's Sound.	117 56	Def. N.	29 23	64	Observed on shore.	1·711	……	·000	1·711	1·672	
			Def. S.	35 31	64		1·657	……	·000	1·657		
			Def. N.S.	50 11	64		1·679	……	·000	1·679		
			Mag. N.	31 37	64		1·658	……	·000	1·658		
			Mag. S.	36 25	62		1·653	……	·000	1·653		
			wt. 1 gr.	16 13	62		1·693	……	·000	1·693	1·688	
			wt. 1½ gr.	24 39	62		1·672	……	·000	1·672		
			wt. 2 grs.	33 27	62		1·698	……	·000	1·698		
23.	—35 30	114 35	Def. N.	30 03	66	N.W.	1·670	—·011	—·001	1·658	1·672	Very unsteady, heavy south-west swell.
			Def. S.	35 01	66	N.W.	1·687	—·011	—·001	1·675		
			Def. N.S.	49 55	66	N.W.	1·696	—·011	—·002	1·683		
25.	—32 24	111 26	Def. N.	31 07	69	N.W. by N.	1·602	—·011	—·001	1·590	1·573	Moderate breeze, table steady.
			Def. S.	36 26	69	N.W. by N.	1·603	—·011	—·001	1·591		
			Def. N.S.	51 30	69	N.W. by N.	1·599	—·011	—·004	1·584		
			Mag. N.	33 14	69	N.W. by N.	1·547	—·011	—·001	1·535		
			Mag. S.	37 23	69	N.W. by N.	1·577	—·011	—·001	1·565		
27.	—29 16	106 49	Def. N.	32 17	72	W.N.W	1·534	—·015	—·001	1·518	1·499	Very unsteady.
			Def. S.	37 53	72	W.N.W.	1·515	—·015	—·001	1·499		
			Def. N.S.	53 15	72	W.N.W.	1·501	—·015	—·005	1·481		

* Omitted in mean.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Ap. 28.	−27° 35′	106° 32′	Def. N.	33° 30′	75°	N. by W.	1·467	+·002	−·001	1·468	1·478	Unsteady, a heavy swell.
			Def. S.	37 36	76	N. by W.	1·532	+·002	−·001	1·533		
			Def. N.S.	53 30	76	N. by W.	1·483	+·002	−·006	1·479		
			Mag. N.	34 36	76	N. by W.	1·459	+·002	−·002	1·459		
			Mag. S.	39 06	76	N. by W.	1·451	+·002	−·002	1·451		
29.	−25 46	104 55	Def. N.	33 47	68	N.W.	1·450	−·003	−·001	1·446	1·447	Very unsteady.
			Def. S.	39 02	68	N.W.	1·453	−·003	−·001	1·449		
May 1.	−23 58	99 06	Def. N.	34 30	68	W.	1·414	−·022	−·001	1·391	1·381	Unsteady.
			Def. S.	39 54	68	W.	1·407	−·022	−·001	1·384		
			Def. N.S.	55 14	68	W.	1·394	−·022	−·003	1·369		
2.	−24 01	97 25	Def. N.	34 32	72	W. ½ N.	1·412	−·019	−·001	1·392	1·381	Unsteady.
			Def. S.	40 02	72	W. ½ N.	1·402	−·019	−·001	1·382		
			Def. N.S.	55 15	72	W. ½ N.	1·394	−·019	−·005	1·370		
3.	−23 50	95 56	Def. N.	35 00	76	W. ½ N.	1·388	−·019	−·001	1·368	1·377	Steady.
			Def. S.	40 16	76	W. ½ N.	1·389	−·019	−·001	1·369		
			Def. N.S.	55 38	76	W. ½ N.	1·378	−·019	−·006	1·353		
			wt. 1 gr.	19 28	76	W. ½ N.	1·419	−·019	+·001	1·401		
			wt. 1½ gr.	29 58	76	W. ½ N.	1·396	−·019	+·001	1·378		
			wt. 2 grs.	41 30	76	W. ½ N.	1·413	−·019	+·001	1·395		
4.	−24 16	93 48	Def. N.	35 21	76	W.N.W.	1·371	−·010	−·001	1·360	1·352	Unsteady.
			Def. S.	41 05	76	W.N.W.	1·350	−·010	−·001	1·339		
			Def. N.S.	55 45	76	W.N.W.	1·369	−·010	−·001	1·358		
5.	−24 02	92 07	Def. N.	35 51	73	N.W.	1·347	+·008	−·001	1·354	1·367	Cross sea, much rolling motion.
			Def. S.	40 37	73	N.W.	1·373	+·008	−·001	1·380		
7.	−21 44	89 38	Def. N.	36 30	73	N.W. ½ W.	1·316	+·004	−·001	1·319	1·314	Table unsteady.
			Def. S.	42 13	73	N.W. ½ W.	1·298	+·004	−·001	1·301		
			Def. N.S.	56 45	73	N.W. ½ W.	1·322	+·004	−·005	1·321		
8.	−20 38	87 50	Def. N.	36 39	77	N.W. ½ W.	1·309	+·004	−·001	1·312	1·298	Unsteady.
			Def. S.	42 49	77	N.W. ½ W.	1·270	+·004	−·001	1·273		
			Def. N.S.	56 58	77	N.W. ½ W.	1·312	+·004	−·006	1·310		
9.	−20 37	85 02	Def. N.	36 56	77	W. ½ N.	1·295	−·015	−·001	1·279	1·263	Heavy swell.
			Def. S.	42 49	77	W. ½ N.	1·270	−·015	−·001	1·254		
			Def. N.S.	57 46	77	W. ½ N.	1·276	−·015	−·006	1·255		
10.	−20 25	82 10	Def. N.	37 46	77	W. ¾ N.	1·260	−·012	−·001	1·247	1·248	Heavy swell.
			Def. S.	42 48	76	W. ¾ N.	1·270	−·012	−·001	1·257		
			Def. N.S.	57 46	76	W. ¾ N.	1·276	−·012	−·006	1·258		
			Mag. N.	38 04	76	W. ¾ N.	1·256	−·012	−·001	1·243		
			Mag. S.	42 13	76	W. ¾ N.	1·249	−·012	−·001	1·236		
11.	−20 36	79 10	Def. N.	39 00	78	W. ¾ N.	1·207	−·012	−·001	1·194	1·213	Unsteady.
			Def. S.	43 29	78	W. ¾ N.	1·239	−·012	−·001	1·226		
			Def. N.S.	58 28	78	W. ¾ N.	1·247	−·012	−·007	1·228		
			Mag. S.	42 44	78	W. ¾ N.	1·220	−·012	−·002	1·206		
12.	−20 44	78 31	Def. N.	37 23	87	S.	1·275	−·040	−·002	1·233	1·234	These observations were made to determine the effec of the ship's iro at sea.
			Def. N.	37 12	87	S.S.W.	1·283	−·036	−·002	1·245		
			Def. N.	37 14	87	S.W.	1·282	−·032	−·002	1·248		
			Def. N.	38 13	87	W.S.W.	1·241	−·023	−·002	1·216		
			Def. N.	38 28	87	W.	1·229	−·016	−·002	1·211		
			Def. N.	38 27	87	W.N.W.	1·230	−·007	−·002	1·221		
			Def. N.	37 47	86	N.W.	1·258	−·001	−·002	1·255		
			Def. N.	38 14	84	N.N.W.	1·240	·000	−·002	1·238		
			Def. N.	38 11	80	N.	1·242	+·002	−·001	1·243		
			Def. N.	38 28	78	N.N.E.	1·229	·000	−·001	1·228		
			Def. N.	38 17	78	N.E.	1·236	−·001	−·001	1·234		
			Def. N.	38 00	78	E.N.E.	1·249	−·007	−·001	1·241		

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. May 13.	−20° 39′	77° 43′	Def. N.	37° 41′	81°	S.E.	1·262	—·032	—·001	1·229		
			Def. N.	38 00	81	E.	1·249	—·016	—·001	1·232		Made to determine the effect of the ship's iron at sea.
			Def. N.	37 40	81	N.E.	1·264	—·001	—·001	1·262		
			Def. N.	38 24	80	N.	1·232	+·002	—·001	1·233	1·233	
			Def. N.	38 31	79	N.W.	1·228	—·001	—·001	1·226		A rolling motion, not very steady at some points.
			Def. N.	38 20	79	W.	1·235	—·016	—·001	1·218		
16.	−20 26	70 36	Def. N.	38 40	78	W. by N.	1·221	—·011	—·001	1·209		
			Def. S.	43 52	78	W. by N.	1·221	—·011	—·001	1·209	1·205	Unsteady.
			Def. N.S.	59 26	78	W. by N.	1·214	—·011	—·007	1·196		
17.	−20 34	69 24	Def. N.	38 37	78	W. by N.	1·222	—·011	—·001	1·210		
			Def. S.	43 59	78	W. by N.	1·217	—·011	—·001	1·205		
			Def. N.S.	59 09	78	W. by N.	1·222	—·011	—·007	1·204		
			Def. N.	38 09	79	S.W. by W. ½ W.	1·243	—·030	—·001	1·212		
			Def. S.	43 17	80	S.W. by W. ½ W.	1·248	—·030	—·001	1·217	1·210	Unsteady.
			Def. N.S.	58 34	80	S.W. by W. ½ W.	1·243	—·030	—·007	1·206		
			Mag. N.	38 23	80	S.W. by W. ½ W.	1·237	—·030	—·002	1·205		
			Mag. S.	42 07	80	S.W. by W. ½ W.	1·253	—·030	—·002	1·221		
19.	−21 11	67 54	Def. N.	38 57	76	N.W.	1·209	—·001	—·001	1·207		
			Def. S.	44 17	76	N.W.	1·203	—·001	—·001	1·201		
			Def. N.S.	59 54	76	N.W.	1·196	—·001	—·005	1·190		Unsteady.
			Mag. N.	38 52	76	N.W.	1·211	—·001	—·001	1·209	1·206	
			wt. 1 gr.	22 44	76	N.W.	1·223	—·001	+·001	1·223		
			wt. 1½ gr.	35 01	76	N.W.	1·215	—·001	+·001	1·215		
			wt. 2 grs.	51 35	76	N.W.	1·195	—·001	+·001	1·195		Steady.
20.	−21 12	67 29	Def. N.	39 02	74	W. by N.	1·205	—·012	—·001	1·192		
			Def. S.	44 03	77	W. by N.	1·212	—·012	—·001	1·199	1·190	Unsteady.
			Def. N.S.	59 59	77	W. by N.	1·194	—·012	—·004	1·178		
21.	−21 01	66 10	Def. N.	39 03	76	W. by N.	1·204	—·012	—·001	1·191		
			Def. S.	44 29	76	W. by N.	1·195	—·012	—·001	1·182		
			Def. N.S.	59 40	76	W. by N.	1·204	—·012	—·005	1·187	1·178	Unsteady.
			Mag. N.	39 14	76	W. by N.	1·194	—·012	—·001	1·181		
			Mag. S.	43 48	76	W. by N.	1·163	—·012	—·001	1·150		
22.	−20 40	62 58	Def. N.	39 28	74	W. by N.	1·189	—·012	—·001	1·176		
			Def. S.	45 01	74	W. by N.	1·173	—·012	—·001	1·160	1·173	Table steady.
			Def. N.S.	59 41	74	W. by N.	1·203	—·012	—·005	1·186		
			Mag. N.	39 28	74	W. by N.	1·181	—·012	—·001	1·168		
27.	−20 09	57 31	Def. N.	40 07	77	On shore at Mauritius.	1·165	………	—·001	1·164		
			Def. S.	45 28	77		1·153	………	—·001	1·152		
			Def. N.S.	60 43	77		1·167	………	—·006	1·161	1·155	Steady.
			Mag. N.	39 55	77		1·158	………	—·001	1·157		
			Mag. S.	44 14	77		1·138	………	—·001	1·137		
			wt. 1 gr.	23 59	80		1·163	………	+·001	1·164		
			wt. 1½ gr.*	33 46	80		1·255	………	+·001	1·256*	1·156	Steady.
			wt. 2 grs.	54 42	80		1·147	………	+·001	1·148		
30.	−21 50	53 25	Def. N.	39 41	81	S.W. by W.	1·182	—·027	—·001	1·154		
			Def. S.	44 25	81	S.W. by W.	1·198	—·027	—·001	1·170	1·161	Unsteady.
			Def. N.S.	59 59	80	S.W. by W.	1·194	—·027	—·008	1·159		
June 3.	−26 26	48 20	Def. N.	39 31	79	N.W. by W.	1·187	—·005	—·001	1·181		
			Def. S.	45 18	78	N.W. by W.	1·161	—·005	—·001	1·155	1·164	Unsteady.
			Def. N.S.	60 41	78	N.W. by W.	1·168	—·005	—·006	1·157		
4.	−27 14	45 50	Def. N.	39 44	69	W.	1·179	—·018	—·001	1·160		
			Def. S.	44 39	70	W.	1·188	—·018	—·001	1·169	1·159	Unsteady.
			Def. N.S.	60 38	70	W.	1·169	—·018	—·003	1·148		

* This observation is evidently wrong, and is omitted in the mean.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Temperature.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. June 8.	−28° 57′	37° 55′	Def. N.	40° 36′	74°	w.	1·147	—·018	—·001	1·128	1·111	Steady.
			Def. S.	46 11	76	w.	1·124	—·018	—·001	1·105		
			Def. N.S.	61 44	77	w.	1·131	—·018	—·005	1·108		
			Mag. N.	40 27	77	w.	1·132	—·018	—·001	1·113		
			Mag. S.	44 33	77	w.	1·121	—·018	—·001	1·102		
11.	−30 27	33 41	Def. N.	41 32	79	w.n.w.	1·114	—·008	—·001	1·105	1·105	Very unsteady.
13.	−31 06	31 26	Def. N.	41 58	79	w. by s. ½ s.	1·098	—·024	—·001	1·073	1·063	
			Def. S.	47 30	79	w. by s. ½ s.	1·079	—·024	—·001	1·054		
			Def. N.S.	61 41	79	w. by s. ½ s.	1·131*	—·024	—·006	1·101*		
17.	−35 40	21 40	Def. N.	43 12	62	w. by n.	1·053	—·013	·000	1·040	1·033	Unsteady.
			Def. N.S.	64 49	62	w. by n.	1·038	—·013	·000	1·025		
23.	Simon's Bay, Cape of Good Hope.		Def. N.	43 22	68	s.	1·047	—·040	—·001	1·006	1·001	
			Def. N.	43 41	67	s.e.	1·036	—·032	·000	1·004		
			Def. N.	44 14	67	e.	1·117	—·016	·000	1·001		
			Def. N.	44 35	67	n.e.	1·004	—·001	·000	1·003		
			Def. N.	44 40	67	n.	1·001	+·002	·000	1·003		
			Def. N.	44 46	67	n.w.	1·997	—·001	·000	0·996		
			Def. N.	44 20	70	w.	1·013	—·016	—·001	0·996		
			Def. N.	43 50	70	s.w.	1·032	—·032	—·001	0·999		
24.	Simon's Bay, at the Dock Yard.		Def. N.	44 38	68	Face East, on shore.	1·004	....	—·001	1·003	1·001	
			Def. S.	50 14	68		0·990*	....	—·001	0·989*		
			Def. N.S.	66 16	68		1·002	....	—·002	1·000		
30.			Needle N.	45 01	61	On shore.	0·989	....	·000	0·989	1·000	
			Needle S.	49 59	62		0·996	....	·000	0·996		
			Mag. N.S.	66 20	63		0·997	....	—·001	0·996		
			Mag. N.	43 45	64		0·989	....	·000	0·989		
			Mag. S.	47 23	64		0·997	....	·000	0·997		
July 2.			Needle N.	44 33	61	On shore.	1·005	....	·000	1·005		
			Needle S.	49 42	62		1·005	....	·000	1·005		
			Needle N.S.	66 16	63		0·998	....	—·001	0·997		
			Mag. N.	43 15	63		1·006	....	·000	1·006		
			Mag. S.	47 20	64		0·999	....	·000	0·999		
			wt. 1 gr.	28 26	56		0·993	....	·000	0·993		
			wt. 1½ gr.	44 16	57		0·999	....	·000	0·999		
			wt. 2 grs.	69 15	58		1·001	....	·000	1·001		
11.	Magnetic Observatory, Cape of Good Hope.		Def. N.	44 31	75	On shore.	1·006	....	—·001	1·005		
			Def. S.	49 48	75		1·002	....	—·001	1·001		
			Mag. N.S.	66 02	75		1·003	....	—·004	0·999		
			Mag. N.	43 21	76		1·002	....	—·001	1·001		
			Mag. S.	47 13	76		1·004	....	—·001	1·003		
			wt. 1 gr.	28 00	76		1·007	....	+·001	1·008		
			wt. 1½ gr.	44 10	76		1·001	....	+·001	1·002		
			wt. 2 grs.	69 31	76		0·999	....	+·001	1·000		

* Not included in mean.

Observations of the Magnetic Force made on board Her Majesty's hired Bark "Pagoda," from the 1st of December 1844 to the 2nd of July 1845. Needle 1. Fox No. 1.; Face West; time usually two hours before Noon.

Observer, Lieut. H. Clerk, R.A.

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1844. Dec. 1.	−33° 56′	18° 29′	Def. N.	39° 06′	65°	Observed on shore.	1·006	....	·000	1·006	0·999	
			Def. S.	40 38	67		1·001	....	−·001	1·000		
			Def. N.S.	59 23	68		0·981	....	−·001	0·980		
			wt. 1 gr.	21 29	70		1·009	....	+·001	1·010		
			wt. 2 grs.	46 54	71		0·995	....	+·001	0·996		
			wt. 2½ grs.	65 22	72		1·000	....	+·001	1·001		
5.	Magnetic Observatory, Cape of Good Hope.		Def. N.	39 01	72		1·008	....	−·001	1·007		
			Def. S.	40 37	72		1·001	....	−·001	1·000		
			Def. N.S.	59 22	73		0·983	....	−·003	0·980		
			wt. 1 gr.	21 34	74		1·006	....	+·001	1·007		
			wt. 2 grs.	46 33	74		1·001	....	+·001	1·002		
			wt. 2½ grs.	65 19	74		1·001	....	+·001	1·002		
21.	−34 12	18 26	Def. N.	39 04	74	Observed on shore.	1·007	....	−·001	1·006	1·005	
			Def. S.	40 25	76		1·007	....	−·001	1·006		
	Dock Yard, Simon's Bay.		Def. N.S.	59 11	78		0·998	....	−·004	0·984		
			wt. 1 gr.	21 04	78		1·029	....	+·001	1·030		
			wt. 2 grs.	46 30	78		1·002	....	+·001	1·003		
			wt. 2½ grs.	65 49	78		0·997	....	+·001	0·908		
1845. Jan. 10.	−34 44	17 50	Def. N.	39 42	70	w. by n.	0·986	−·009	−·001	0·976	0·981	Table unsteady.
			Def. S.	40 39	70	w. by n.	1·000	−·009	−·001	0·990		
			Def. N.S.	59 11	70	w. by n.	0·988	−·009	−·002	0·977		
13.	−35 12	13 28	Def. N.	40 02	72	s.w. by w.	0·976	−·030	−·001	0·945	0·950	Table steady.
			Def. S.	40 40	72	s.w. by w.	0·999	−·030	−·001	0·968		
			Def. N.S.	59 25	75	s.w. ½ w.	0·980	−·040	−·003	0·937		
			wt. 1 gr.	22 00	70	s.w. ½ w.	0·987	−·040	+·001	0·948		
			wt. 2 grs.	47 02	69	s.w. ½ w.	0·992	−·040	+·001	0·953		
			wt. 2½ grs.	67 01	68	s.w. ½ w.	0·987	−·040	+·001	0·948		
14.	−37 25	13 24	Def. N.	38 52	65	s. by w.	1·013	−·042	·000	0·971	0·965	Table unsteady.
			Def. S.	40 22	65	s. by w.	1·009	−·042	·000	0·967		
			Def. N.S.	58 50	65	s. by w.	1·000	−·042	−·001	0·957		
15.	−38 37	14 27	Def. N.	38 55	62	n.w. by w.	1·012	+·003	·000	1·015	1·008	Very unsteady.
			Def. S.	39 55	62	n.w. by w.	1·023	+·003	·000	1·026		
			Def. N.S.	59 25	66	n.w. by w.	0·980	+·003	−·001	0·982		
16.	−39 10	14 41	Def. N.	38 47	63	s.w.byw.½w.	1·016	−·026	·000	0·990	0·989	Table steady.
			Def. S.	39 35	63	s.w.byw.½w.	1·034	−·026	·000	1·008		
			Def. N.S.	58 30	63	s.w.byw.½w.	1·009	−·026	−·001	0·982		
			wt. 1 gr.	21 32	64	s.w.byw.½w.	1·008	−·026	·000	0·982		
			wt. 2 grs.	45 22	65	s.w.byw.½w.	1·021	−·026	·000	0·995		
			wt. 2½ grs.	64 42	67	s.w.byw.½w.	1·005	−·026	·000	0·979		
17.	−40 21	14 29	Def. N.	38 42	64	s.w. by w.	1·019	−·029	·000	0·990	0·994	Much motion.
			Def. S.	39 25	65	s.w. by w.	1·039	−·029	·000	1·010		
			Def. N.S.	58 27	65	s.w. by w.	1·011	−·029	−·001	0·981		
18.	−42 50	13 00	Def. N.	38 32	60	s.s.w.	1·025	−·040	·000	0·985	0·997	Much motion.
			Def. S.	38 35	59	s.s.w.	1·066	−·040	·000	1·026		
			Def. N.S.	58 07	58	s.s.w.	1·021	−·040	·000	0·981		
19.	−44 50	13 19	Def. N.	38 17	48	s.w. by s.	1·033	−·037	+·001	0·997	1·007	Much motion.
			Def. S.	39 02	45	s.w. by s.	1·051	−·037	+·001	1·015		
			Def. N.S.	57 27	44	s.w. by s.	1·044	−·037	+·003	1·010		

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Jan. 21.	−47° 40′	12° 25′	Def. N.	36° 30′	43°	S. by E.	1·091	−·041	+·001	1·051	1·051	Very unsteady.
22.	−48 35	10 51	Def. N.	36 15	48	S.W. by S.	1·101	−·037	+·001	1·065	1·060	Table steady.
			Def. S.	37 35	48	S.W. by S.	1·104	−·037	+·001	1·068		
			Def. N.S.	56 28	47	S.W. by S.	1·080	−·037	+·003	1·046		
23.	−50 30	10 25	Def. N.	35 10	43	S.W. ½ S.	1·140	−·036	+·001	1·105	1·094	Table steady.
			Def. S.	36 37	43	S.W. ½ S.	1·141	−·036	+·001	1·106		
			Def. N.S.	55 47	43	S.W. ½ S.	1·105	−·036	+·003	1·072		
24.	−51 48	9 33	Def. N.	34 47	48	S.W. by W.	1·154	−·029	+·001	1·126	1·120	Table steady.
			Def. S.	36 10	47	S.W. by W.	1·158	−·029	+·001	1·130		
			Def. N.S.	55 07	47	S.W. by W.	1·131	−·029	+·003	1·105		
25.	−52 53	7 53	Def. N.	34 57	41	S.W. by W.	1·148	−·029	+·001	1·120	1·122	Rather unsteady.
			Def. S.	35 47	41	S.W. by W.	1·173	−·029	+·001	1·145		
			Def. N.S.	55 17	40	S.W. by W.	1·125	−·029	+·004	1·100		
26.	−53 52	6 07	Def. N.	34 22	43	W. by S.	1·171	−·020	+·001	1·152	1·143	Very steady.
			Def. S.	35 42	43	W. by S.	1·175	−·020	+·001	1·156		
			Def. N.S.	54 30	42	W. by S.	1·155	−·020	+·003	1·138		
			wt. 1 gr.	18 12	41	W. by S.	1·185	−·020	−·001	1·164		
			wt. 2 grs.	39 40	40	W. by S.	1·138	−·020	−·001	1·117		
			wt. 2½ grs.	51 50	41	W. by S.	1·155	−·020	−·001	1·134		
27.	−55 08	5 50	Def. N.	33 05	39	S.S.W. ½ W.	1·221	−·038	+·002	1·185	1·161	Very unsteady.
			Def. S.	35 52	38	S.S.W. ½ W.	1·201	−·038	+·002	1·165		
			Def. N.S.	54 12	37	S.S.W. ½ W.	1·167	−·038	+·005	1·134		
30.	−60 43	4 00	Def. N.S.	51 57	35	S.	1·262	−·049	+·006	1·219	1·240	Table unsteady.
			Def. N.S.	51 35	34	S.E. by E.	1·282	−·034	+·006	1·254		
			Def. N.S.	52 22	34	N.	1·246	−·004	+·006	1·248		
31.	−61 05	9 03	Def. N.	30 57	42	S.E. by S.	1·320	−·044	+·002	1·278	1·285	Table steady.
			Def. S.	31 55	42	S.E. by S.	1·339	−·044	+·002	1·297		
			Def. N.S.	51 22	41	S.E. by S.	1·294	−·044	+·005	1·255		
			wt. 1 gr.	16 02	41	S.E. by S.	1·340	−·044	−·001	1·295		
			wt. 2 grs.	32 22	41	S.E. by S.	1·343	−·044	−·001	1·298		
			wt. 2½ grs.	43 02	41	S.E. by S.	1·332	−·044	−·001	1·287		
Feb. 2.	−61 54	16 23	Def. N.	29 57	40	E.S.E.	1·368	−·032	+·003	1·339	1·331	Table unsteady.
			Def. S.	30 57	39	E.S.E.	1·384	−·032	+·003	1·355		
			Def. N.S.	50 45	38	E.S.E.	1·325	−·032	+·006	1·299		
3.	−61 50	19 13	Def. N.	30 10	41	E.S.E.	1·348	−·032	+·002	1·318	1·334	Very steady.
			Def. S.	31 20	41	E.S.E.	1·366	−·032	+·002	1·336		
			Def. N.S.	50 20	40	E.S.E.	1·346	−·032	+·006	1·320		
			wt. 1 gr.	15 05	38	E.S.E.	1·420	−·032	−·002	1·386		
			wt. 2 grs.	31 55	38	E.S.E.	1·376	−·032	−·002	1·342		
			wt. 2½ grs.	42 57	38	E.S.E.	1·336	−·032	+·002	1·302		
4.	−62 00	20 25	Def. N.	29 30	38	S.S.E.	1·388	−·046	+·003	1·345	1·353	Very steady.
			Def. S.	30 37	37	S.S.E.	1·401	−·046	+·003	1·358		
			Def. N.S.	49 27	37	S.S.E.	1·396	−·046	+·006	1·356		
6.	−64 20	24 05	Def. N.	28 00	37	S.S.E.	1·461	−·050	+·003	1·414	1·401	Very steady.
			Def. S.	29 57	37	S.S.E.	1·435	−·050	+·003	1·388		
			Def. N.S.	49 02	37	S.S.E.	1·422	−·050	+·007	1·379		
			wt. 1 gr.	14 17	36	S.S.E.	1·499	−·050	−·002	1·447		
			wt. 2 grs.	30 00	36	S.S.E.	1·454	−·050	−·002	1·402		
			wt. 2½ grs.	39 40	36	S.S.E.	1·425	−·050	−·002	1·373		
7.	−65 34	28 30	Def. N.	27 37	41	S.S.E. ½ E.	1·481	−·049	+·002	1·434	1·432	Very steady.
			Def. S.	28 57	42	S.S.E. ½ E.	1·486	−·049	+·002	1·439		
			Def. N.S.	48 17	42	S.S.E. ½ E.	1·466	−·049	+·005	1·422		
9.	−66 30	36 46	Def. N.	26 52	34	E.	1·519	−·026	+·004	1·497	1·482	Very steady.
			Def. S.	28 35	33	E.	1·506	−·026	+·004	1·484		
			Def. N.S.	48 00	32	E.	1·483	−·026	+·008	1·465		
10.	−66 43	38 49	Def. N.	26 15	34	S.S.W.	1·553	−·050	+·004	1·507	1·491	Very steady.
			Def. S.	28 00	34	S.S.W.	1·538	−·050	+·004	1·492		
			Def. N.S.	47 30	34	S.S.W.	1·516	−·050	+·007	1·473		

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Feb. 11.	−67° 35′	39° 31′	Def. N.	26° 35′	33°	N.E.	1·534	—·016	+·004	1·522	1·519	Very unsteady.
			Def. S.	27 55	32	N.E.	1·544	—·016	+·004	1·532		
			Def. N.S.	47 35	31	N.E.	1·510	—·016	+·008	1·502		
12.	—66 45	39 23	Def. N.	26 12	37	S.S.E.	1·556	—·049	+·003	1·510	1·494	Very unsteady.
			Def. S.	28 17	37	S.S.E.	1·522	—·049	+·003	1·476		
			Def. N.S.	47 12	37	S.S.E.	1·537	—·049	+·007	1·495		
13.	—67 00	40 07	Def. N.	26 22	37	E.N.E.	1·547	—·025	+·003	1·525	1·499	Table steady.
			Def. S.	28 10	36	E.N.E.	1·529	—·025	+·003	1·507		
			Def. N.S.	47 42	35	E.N.E.	1·504	—·025	+·007	1·486		
			wt. 1 gr.	14 00	32	E.N.E.	1·529	—·025	—·002	1·502		
			wt. 2 grs.	28 17	32	E.N.E.	1·534	—·025	—·002	1·507		
			wt. 2½ grs.	37 27	32	E.N.E.	1·496	—·025	—·002	1·469		
16.	—64 52	38 37	Def. N.	27 10	37	S. ¾ E.	1·504	—·053	+·003	1·454	1·470	Very unsteady.
			Def. S.	28 02	37	S. ¾ E.	1·536	—·053	+·003	1·486		
17.	—64 52	40 12	Def. N.	27 34	38	N. by W.	1·488	—·019	+·003	1·472	1·463	Very unsteady.
			Def. S.	29 12	38	N. by W.	1·473	—·019	+·003	1·457		
			Def. N.S.	48 10	38	N. by W.	1·473	—·019	+·006	1·460		
18.	—64 22	40 49	Def. N.	26 52	38	S. by E.	1·519	—·053	+·003	1·469	1·460	Very unsteady.
			Def. S.	28 42	37	S. by E.	1·500	—·053	+·003	1·450		
19.	—63 49	42 00	Def. N.	28 35	39	E. by S.	1·431	—·053	+·003	1·399	1·416	Very unsteady.
			Def. S.	29 47	37	E. by S.	1·443	—·035	+·003	1·411		
			Def. N.S.	48 15	36	E. by S.	1·468	—·035	+·006	1·439		
20.	—63 22	45 35	Def. S.	29 02	44	S.E. by E. ½ E.	1·482	—·049	+·002	1·435	1·437	Very unsteady.
			Def. N.S.	48 00	45	S.E. by E. ½ E.	1·483	—·049	+·005	1·439		
21.	—63 36	46 41	Def. N.	27 00	42	S.S.E.	1·512	—·049	+·002	1·465	1·457	Table unsteady.
			Def. S.	28 37	41	S.S.E.	1·505	—·049	+·002	1·458		
			Def. N.S.	47 52	41	S.S.E.	1·491	—·049	+·006	1·448		
24.	—62 36	51 40	Def. N.S.	47 54	36	E.	1·490	—·031	+·007	1·466	1·466	Very unsteady.
			Def. N.	26 45	36	E.	1·526	—·031	+·003	1·498		
			Def. S.	29 27	34	E.	1·460	—·031	+·004	1·433		
25.	—61 25	53 38	Def. N.	27 05	40	E.S.E.	1·507	—·039	+·003	1·471	1·476	Unsteady.
			Def. S.	28 32	39	E.S.E.	1·510	—·039	+·003	1·474		
			Def. N.S.	47 30	38	E.S.E.	1·516	—·039	+·006	1·483		
26.	—61 17	57 28	Def. N.	25 30	41	S.E. ½ E.	1·595	—·044	+·002	1·553	1·535	Table unsteady.
			Def. S.	27 30	42	S.E. ½ E.	1·566	—·044	+·002	1·524		
			Def. N.S.	46 45	44	S.E. ½ E.	1·567	—·044	+·005	1·528		
27.	—61 00	64 03	Def. N.	25 17	37	S.E. ½ S.	1·607	—·050	+·003	1·560	1·553	Table steady.
			Def. S.	26 30	36	S.E. ½ S.	1·622	—·050	+·004	1·576		
			Def. N.S.	46 47	35	S.E. ½ S.	1·564	—·050	+·008	1·522		
28.	—61 36	70 46	Def. N.	24 22	40	S.S.E.	1·660	—·052	+·003	1·611	1·604	Table unsteady.
			Def. S.	25 57	39	S.S.E.	1·654	—·052	+·003	1·605		
			Def. N.S.	45 42	38	S.S.E.	1·640	—·052	+·007	1·595		
Mar. 1.	—62 10	72 25	Def. N.	23 10	44	S.S.E.	1·731	—·052	+·002	1·681	1·657	Table steady.
			Def. S.	25 37	44	S.S.E.	1·674	—·052	+·002	1·624		
			Def. N.S.	44 50	44	S.S.E.	1·705	—·052	+·005	1·658		
			wt. 1 gr.	11 37	44	S.S.E.	1·837	—·052	—·001	1·784*		
			wt. 2 grs.	25 00	43	S.S.E.	1·719	—·052	—·001	1·666		
			wt. 2½ grs.	32 12	43	S.S.E.	1·708	—·052	—·001	1·655		
2.	—62 40	76 09	Def. N.	23 50	42	S.	1·693	—·056	+·002	1·639	1·656	Very steady.
			Def. S.	25 10	42	S.	1·699	—·056	+·002	1·645		
			Def. N.S.	44 45	41	S.	1·710	—·056	+·006	1·660		
			wt. 1 gr.	11 35	39	S.	1·838	—·056	—·001	1·781*		
			wt. 2 grs.	24 47	39	S.	1·733	—·056	—·001	1·676		
			wt. 2½ grs.	32 00	39	S.	1·718	—·056	—·001	1·661		

* Not included in the mean; angle of deflection become too small.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845.												
Mar. 3.	−64° 20′	79° 38′	Def. N.	22° 38′	33°	s. by w. ½ w.	1·763	—·055	+·004	1·712	1·706	Table unsteady.
			Def. S.	24 17	32	s. by w. ½ w.	1·754	—·055	+·004	1·703		
			Def. N.S.	44 12	32	s. by w. ½ w.	1·750	—·055	+·009	1·704		
5.	−61 38	84 40	Def. N.	23 02	39	s.e.	1·740	—·051	+·003	1·692	1·689	Table unsteady.
			Def. S.	24 20	40	s.e.	1·752	—·051	+·003	1·704		
			Def. N.S.	44 40	41	s.e.	1·716	—·051	+·007	1·672		
6.	−60 42	88 12	Def. N.	22 40	36	n.e. ½ n.	1·761	—·025	+·004	1·740	1·729	Table unsteady.
			Def. S.	23 55	36	n.e. ½ n.	1·780	—·025	+·004	1·759		
			Def. N.S.	44 50	35	n.e. ½ n.	1·705	—·025	+·008	1·688		
7.	−61 20	91 09	Def. N.	22 02	40	s. by e.	1·800	—·055	+·003	1·748	1·761	
			Def. S.	23 05	41	s. by e.	1·831	—·055	+·003	1·779		
			Def. N.S.	43 30	42	s. by e.	1·805	—·055	+·007	1·757		
	−61 26	91 20	Def. N.	22 00	40	s.w. by s.	1·801	—·054	+·004	1·751	1·756	Table unsteady.
			Def. S.	23 22	40	s.w. by s.	1·812	—·054	+·004	1·762		
			Def. N.S.	43 37	39	s.w. by s.	1·800	—·054	+·008	1·754		
8.	−61 14	92 03	Def. N.	22 05	39	e.	1·795	—·042	+·004	1·757	1·762	Table steady.
			Def. S.	23 37	38	e.	1·796	—·042	+·004	1·758		
			Def. N.S.	43 32	37	e.	1·804	—·042	+·008	1·770		
			wt. 1 gr.	11 17	36	e.	1·890	—·045	—·002	1·843*		
			wt. 2 grs.	23 50	35	e.	1·801	—·045	—·002	1·754*		
			wt. 2½ grs.	29 05	34	e.	1·870	—·045	—·002	1·823*		
9.	−60 35	92 25	Def. N.	22 17	41	e.	1·783	—·045	+·003	1·741	1·745	Table unsteady.
			Def. S.	23 55	37	e.	1·780	—·045	+·004	1·739		
			Def. N.S.	43 40	38	e.	1·791	—·045	+·008	1·754		
10.	−60 03	95 36	Def. N.	20 57	36	s.e. ½ s.	1·867	—·055	+·004	1·816	1·798	Very unsteady.
			Def. S.	23 07	36	s.e. ½ s.	1·831	—·055	+·004	1·780		
11.	−59 52	99 30	Def. N.	21 05	38	e. ½ s.	1·810	—·047	+·004	1·767	1·770	Very unsteady.
			Def. S.	22 57	37	e. ½ s.	1·839	—·047	+·004	1·796		
			Def. N.S.	43 45	36	e. ½ s.	1·785	—·047	+·009	1·747		
	−59 59	99 39	Def. N.	21 42	40	e. ½ n.	1·820	—·042	+·004	1·782	1·773	Table unsteady 5 p.m.
			Def. S.	23 32	40	e. ½ n.	1·804	—·042	+·004	1·766		
			Def. N.S.	43 25	39	e. ½ n.	1·813	—·042	+·008	1·779		
			wt. 1 gr.	11 20	35	e. ½ n.	1·884	—·042	—·003	1·839*		
			wt. 2 grs.	23 42	35	e. ½ n.	1·810	—·042	—·003	1·763		
			wt. 2½ grs.	30 02	34	e. ½ n.	1·820	—·042	—·003	1·775		
13.	−57 35	99 28	Def. N.S.	41 05	35	e. by s.	2·006	—·047	+·009	1·968	1·968	Very unsteady 6 p.m.
14.	−56 53	101 24	Def. N.	21 15	41	e. by s.	1·848	—·047	+·003	1·804	1·786	Very unsteady.
			Def. S.	22 57	41	e. by s.	1·839	—·047	+·003	1·795		
			Def. N.S.	43 35	40	e. by s.	1·800	—·047	+·007	1·760		
15.	−55 52	103 06	Def. N.	21 15	39	e. by n.	1·848	—·042	+·004	1·810	1·816	Very unsteady.
			Def. S.	22 35	39	e. by n.	1·864	—·042	+·004	1·826		
			Def. N.S.	43 00	38	e. by n.	1·845	—·042	+·008	1·811		
16.	−54 48	106 04	Def. N.	21 30	40	n.e.	1·832	—·036	+·004	1·800	1·801	Very unsteady.
			Def. S.	22 52	40	n.e.	1·844	—·036	+·004	1·812		
			Def. N.S.	43 20	39	n.e.	1·819	—·036	+·008	1·791		
17.	−54 17	108 05	Def. N.	20 20	41	s.e.	1·912	—·054	+·004	1·862	1·816	Very unsteady, ship pitching heavily.
			Def. S.	22 22	41	s.e.	1·878	—·054	+·004	1·828		
			Def. N.	21 35	40	e.	1·826	—·045	+·004	1·785		
			Def. S.	23 10	40	e.	1·830	—·045	+·004	1·789		
18.	−53 00	110 08	Def. N.	21 37	40	n.n.e. ½ e.	1·825	—·034	+·004	1·795	1·814	Very unsteady, a heavy swell.
			Def. S.	22 40	40	n.n.e. ½ e.	1·858	—·034	+·004	1·828		
			Def. N.S.	42 57	39	n.n.e. ½ e.	1·846	—·034	+·008	1·820		
19.	−51 20	111 23	Def. S.	23 20	41	n.n.e. ½ e.	1·816	—·034	+·004	1·786	1·787	Very unsteady, a heavy swell.
			Def. N.S.	43 22	41	n.n.e. ½ e.	1·818	—·034	+·004	1·788		

* Not included in the mean.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. Mar. 20.	−49° 01′	111° 47′	Def. N.	21° 20′	45°	N.E. by N.	1·843	−·027	+·003	1·819	1·798	Table unsteady, swell from west.
			Def. S.	23 32	45	N.E. by N.	1·805	−·027	+·003	1·781		
			Def. N.S.	43 15	45	N.E. by N.	1·825	−·027	+·006	1·804		
			wt. 1 gr.	11 10	44	N.E. by N.	1·911	−·027	−·002	1·882†		
			wt. 2 grs.	23 32	44	N.E. by N.	1·823	−·027	−·002	1·794		
			wt. 2½ grs.	30 02	45	N.E. by N.	1·820	−·027	−·002	1·791		
22.	−47 21	115 15	Def. N.	21 05	49	E.N.E.	1·857	−·035	+·002	1·824	1·825	Steady, light swell from west.
			Def. S.	22 10	49	E.N.E.	1·892	−·035	+·002	1·859		
			Def. N.S.	43 20	48	E.N.E.	1·821	−·035	+·005	1·791		
25.	−43 20	116 52	Def. N.	23 27*	51	N. ½ E.	1·712	−·025	+·002	1·689†	1·760	Very unsteady, heavy swell from west.
			Def. S.	23 35	51	N. ½ E.	1·799	−·025	+·002	1·776		
			Def. N.S.	43 45	51	N. ½ E.	1·785	−·025	+·003	1·763		
			wt. 1 gr.	12 07	50	N. ½ E.	1·764	−·025	−·001	1·738		
			wt. 2 grs.	23 32	50	N. ½ E.	1·823	−·025	−·001	1·797		
			wt. 2½ grs.	31 17	50	N. ½ E.	1·752	−·025	−·001	1·726		
26.	−41 18	116 09	Def. N.	22 30	54	N. by W.	1·771	−·020	+·001	1·752	1·746	Unsteady, light swell.
			Def. S.	23 57	54	N. by W.	1·776	−·020	+·001	1·757		
			Def. N.S.	44 15	54	N. by W.	1·747	−·020	+·002	1·729		
27.	−38 52	116 15	Def. N.	22 37	58	N. by W.	1·765	−·012	·000	1·753	1·738	Table steady.
			Def. S.	23 52	58	N. by W.	1·770	−·012	·000	1·758		
			Def. N.S.	44 40	60	N. by W.	1·716	−·012	·000	1·704		
28.	−37 03	116 57	Def. N.	23 25	59	N. by E.	1·718	−·012	·000	1·706	1·695	Table very steady, nearly a calm.
			Def. S.	24 45	60	N. by E.	1·725	−·012	·000	1·713		
			Def. N.S.	44 30	61	N. by E.	1·728	−·012	·000	1·716		
			wt. 1 gr.	12 45	62	N. by E.	1·678	−·012	·000	1·666		
			wt. 2 grs.	25 40	62	N. by E.	1·678	−·012	·000	1·666		
			wt. 2½ grs.	32 07	63	N. by E.	1·714	−·012	·000	1·702		
29.	−36 12	116 50	Def. N.	23 40	66	N.N.E.	1·701	−·012	−·001	1·688	1·673	Table unsteady.
			Def. S.	25 37	67	N.N.E.	1·673	−·012	−·001	1·660		
			Def. N.S.	45 05	68	N.N.E.	1·685	−·012	−·003	1·670		
30.	−35 18	117 07	Def. N.	23 22	66	N.E. ½ E.	1·719	−·012	−·001	1·706	1·702	Table unsteady.
			Def. S.	24 45	66	N.E. ½ E.	1·725	−·012	−·001	1·712		
			Def. N.S.	44 52	66	N.E. ½ E.	1·701	−·012	−·002	1·687		
April 7.	−35 02	117 56	Def. N.	23 50	68	Observed on shore.	1·692	……..	−·001	1·691	1·688	The observations were made on the same spot where Captains Flinders and Fitzroy had previously observed.
			Def. S.	25 18	68		1·692	……..	−·001	1·691		
			Def. N.S.	45 06	69		1·685	……..	−·001	1·684		
			wt. 1 gr.	12 22	69		1·726	……..	−·001	1·727†		
			wt. 2 grs.	25 24	69		1·695	……..	−·001	1·696		
			wt. 2½ grs.	32 52	68		1·676	……..	−·001	1·677		
11.	King George's Sound, West Australia.		Def. N.	23 42	82		1·700	……..	−·002	1·698		
			Def. S.	25 12	82		1·697	……..	−·002	1·695		
			Def. N.S.	44 59	83		1·692	……..	−·005	1·687		
			wt. 1 gr.	12 37	84		1·692	……..	+·001	1·693		
			wt. 2 grs.	25 30	84		1·689	……..	+·001	1·690		
			wt. 2½ grs.	33 01	85		1·670	……..	+·002	1·672		
19.	At Anchor in the Sound. Swinging the ship for local attraction.		Def. N.S.	44 09	54	S.S.W.	1·754	−·056	+·001	1·699	1·683	The table was very steady during these observations.
			Def. N.S.	44 20	54	S.W.	1·740	−·051	+·001	1·690		
			Def. N.S.	44 30	54	W.S.W.	1·728	−·041	+·001	1·688		
			Def. N.S.	44 44	54	W.	1·710	−·032	+·001	1·679		
			Def. N.S.	44 50	54	W.N.W.	1·702	−·022	+·001	1·681		
			Def. N.S.	45 04	54	N.W.	1·687	−·012	+·001	1·676		
			Def. N.S.	45 01	54	N.N.W.	1·691	−·012	+·001	1·680		
			Def. N.S.	44 59	57	N.	1·692	−·012	+·001	1·681		
			Def. N.S.	45 03	58	N.N.E.	1·688	−·012	·000	1·676		

* The degree should probably be 22°; not included.

† Not included in the mean.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
	° ′	° ′		° ′	°							
1845. Apr. 19.	Swinging the ship for local attraction.		Def. N.S.	45 01	59	N.E.	1·691	—·012	·000	1·679	1·683	Intensity by Def. N.S. on shore 1·685.
			Def. N.S.	44 49	60	E.N.E.	1·702	—·022	·000	1·680		
			Def. N.S.	44 47	60	E.	1·705	—·032	·000	1·673		
			Def. N.S.	44 33	63	E.S.E.	1·723	—·041	—·001	1·681		
			Def. N.S.	44 20	63	S.E.	1·740	—·051	—·001	1·688		
			Def. N.S.	44 14	63	S.S.E.	1·748	—·056	—·001	1·691		
			Def. N.S.	44 11	63	S.	1·751	—·061	—·001	1·689		
23.	—35 36	114 44	Def. N.	23 57	64	N.W.	1·686	—·012	·000	1·674	1·688	Table unsteady.
			Def. S.	24 47	64	N.W.	1·722	—·012	·000	1·710		
			Def. N.S.	45 00	64	N.W.	1·692	—·012	—·001	1·679		
24.	—34 16	113 01	Def. N.	24 40	67	N.W. by N.	1·643	—·012	—·001	1·630	1·641	Table unsteady.
			Def. S.	25 37	69	N.W. by N.	1·674	—·012	—·001	1·661		
			Def. N.S.	45 37	70	N.W. by N.	1·647	—·012	—·002	1·633		
25.	—32 32	111 36	Def. N.	25 02	67	N.W. by N.	1·623	—·008	—·001	1·614	1·613	Table unsteady.
			Def. S.	26 17	69	N.W. by N.	1·634	—·008	—·001	1·625		
			Def. N.S.	46 05	70	N.W. by N.	1·612	—·008	—·003	1·601		
27.	—29 20	106 55	Def. N.	25 07	72	W.N.W.	1·619	—·016	—·002	1·601	1·553	Table steady.
			Def. S.	27 32	72	W.N.W.	1·566	—·016	—·002	1·548		
			Def. N.S.	47 15	72	W.N.W.	1·531	—·016	—·004	1·511		
28.	—27 47	106 36	Def. N.	27 17	68	N. by W. ½ W.	1·497	·000	—·001	1·496	1·490	Very unsteady, heavy swell.
			Def. S.	29 02	69	N. by W. ½ W.	1·482	·000	—·001	1·481		
			Def. N.S.	47 47	69	N. by W. ½ W.	1·497	·000	—·003	1·494		
29.	—26 00	105 11	Def. N.	27 30	72	N.W.	1·486	—·005	—·001	1·480	1·470	Very unsteady, heavy swell.
			Def. S.	29 10	74	N.W.	1·474	—·005	—·001	1·468		
			Def. N.S.	48 12	75	N.W.	1·471	—·005	—·004	1·462		
May 1.	—24 00	99 23	Def. N.	29 07	69	W.	1·396	—·021	—·001	1·374	1·367	Very unsteady, much motion.
			Def. S.	31 00	69	W.	1·381	—·021	—·001	1·359		
			Def. N.S.	49 30	70	W.	1·393	—·021	—·003	1·369		
2.	—24 01	97 30	Def. N.	29 02	70	W. ½ N.	1·410	—·017	—·001	1·392	1·379	Table steady, little motion.
			Def. S.	30 50	71	W. ½ N.	1·390	—·017	—·001	1·372		
			Def. N.S.	49 32	71	W. ½ N.	1·392	—·017	—·003	1·372		
3.	—24 00	96 06	Def. N.	29 40	76	W. ½ N.	1·381	—·017	—·001	1·363	1·365	Table steady, no swell.
			Def. S.	31 02	76	W. ½ N.	1·380	—·017	—·001	1·362		
			Def. N.S.	50 15	77	W. ½ N.	1·350	—·017	—·004	1·329		
			wt. 1 gr.	15 02	77	W. ½ N.	1·423	—·017	+·001	1·407		
			wt. 2 grs.	31 47	76	W. ½ N.	1·380	—·017	+·001	1·364		
			wt. 2½ grs.	41 10	76	W. ½ N.	1·383	—·017	+·001	1·367		
6.	—22 47	91 00	Def. N.	30 57	76	N.W.	1·320	+·008	—·001	1·327	1·324	Very unsteady, heavy westerly swell.
			Def. S.	32 25	79	N.W.	1·315	+·008	—·002	1·321		
			Def. N.S.	60 50	80	N.W.	1·321	+·008	—·005	1·324		
7.	—21 50	89 44	Def. N.	30 45	72	N.W.	1·329	+·008	—·001	1·336	1·326	*
			Def. S.	32 15	74	N.W.	1·322	+·008	—·001	1·329		
			Def. N.S.	51 10	75	N.W.	1·308	+·008	—·004	1·312		
8.	—20 46	87 59	Def. N.	31 45	75	N.W. by W.	1·279	+·004	—·001	1·282	1·294	W. BURDON, Esq., R.N., observer.
			Def. S.	32 20	76	N.W. by W.	1·318	+·004	—·001	1·321		
			Def. N.S.	51 25	77	N.W. by W.	1·292	+·004	—·004	1·292		
			Def. N.	32 00	78	N.W. by W.	1·268	+·004	—·002	1·270		
			Def. S.	32 37	77	N.W. by W.	1·306	+·004	—·001	1·309		
			Def. N.S.	51 27	77	N.W. by W.	1·291	+·004	—·004	1·291		
9.	—20 38	85 26	Def. N.	31 42	77	W. ½ N.	1·286	—·014	—·001	1·271	1·265	Very unsteady, heavy swell.
			Def. S.	33 02	77	W. ½ N.	1·286	—·014	—·001	1·271		
			Def. N.S.	51 50	77	W. ½ N.	1·270	—·014	—·004	1·252		

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. May 10.	−20° 26′	82° 22′	Def. N.	31° 37′	77°	W. ½ N.	1·288	—·014	—·001	1·273	1·257	
			Def. S.	33 15	78	W. ½ N.	1·277	—·014	—·001	1·262		
			Def. N.S.	52 10	80	W. ½ N.	1·260	—·014	—·005	1·241		Very unsteady.
			Def. N.	31 35	75	W. ¼ N.	1·289	—·016	—·001	1·272		
			Def. S.	33 27	75	W. ¼ N.	1·269	—·016	—·001	1·252		W. BURDON, Esq., R.N., observer.
			Def. N.S.	52 07	74	W. ¼ N.	1·260	—·016	—·003	1·241		
11.	−20 36	79 22	Def. N.	31 52	77	W. ¼ N.	1·274	—·016	—·001	1·257	1·247	
			Def. S.	33 37	77	W. ¼ N.	1·262	—·016	—·001	1·245		W. BURDON, Esq., R.N., observer.
			Def. N.S.	52 07	78	W. ¼ N.	1·260	—·016	—·005	1·239		
			Def. N.	31 52	78	W. ¼ N.	1·274	—·016	—·002	1·256		Table unsteady.
			Def. S.	33 40	77	W. ¼ N.	1·260	—·016	—·002	1·242		
			Def. N.S.	52 00	78	W. ¼ N.	1·262	—·016	—·005	1·241		
12.	−20 44	78 31	Def. N.S.	52 17	84	W.	1·249	—·018	—·006	1·225	1·238	
			Def. N.S.	52 20	86	W.N.W.	1·248	—·004	—·006	1·238		
			Def. N.S.	52 32	88	N.W.	1·239	+·008	—·006	1·241		
			Def. N.S.	52 50	91	N.N.W.	1·226	+·006	—·008	1·224		
			Def. N.S.	51 20	80	S.	1·296	—·046	—·005	1·245		Table very unsteady, calm.
			Def. N.S.	51 22	82	S.S.W.	1·294	—·043	—·005	1·246		
			Def. N.S.	51 30	82	S.W.	1·287	—·037	—·005	1·245		
			Def. N.S.	51 55	83	W.S.W.	1·267	—·026	—·005	1·236		
			Def. N.S.	52 25	82	N.N.E.	1·242	+·006	—·005	1·243		
13.	−20 39	77 43	Def. N.S.	52 42	77	W.	1·227	—·018	—·004	1·205	1·237	
			Def. N.S.	52 15	77	N.W.	1·250	+·008	—·004	1·254		
			Def. N.S.	52 32	77	N.	1·239	+·008	—·004	1·243		Very unsteady; calm.
			Def. N.S.	52 22	77	N.E.	1·247	+·008	—·004	1·251		
			Def. N.S.	52 07	78	E.	1·260	—·018	—·005	1·237		
			Def. N.S.	51 45	77	S.E.	1·275	—·037	—·004	1·234		
14.	−20 29	76 22	Def. N.	32 27	76	W. ½ N.	1·249	—·016	—·001	1·232	1·222	
			Def. S.	33 52	76	W. ½ N.	1·252	—·016	—·001	1·235		
			Def. N.S.	52 50	76	W. ½ N.	1·226	—·016	—·004	1·206		Very unsteady.
			Def. N.	33 20	76	W. ½ N.	1·212	—·016	—·001	1·195		
			Def. S.	33 37	76	W. ½ N.	1·262	—·016	—·001	1·245		W. BURDON, Esq., R.N., observer.
			Def. N.S.	52 30	75	W. ½ N.	1·238	—·016	—·004	1·218		
16.	−20 28	70 46	Def. N.	32 45	78	W. ¼ N.	1·236	—·017	—·002	1·217	1·199	
			Def. S.	34 05	78	W. ¼ N.	1·200	—·017	—·002	1·181		Table steady.
			Def. N.S.	52 55	78	W. ¼ N.	1·222	—·017	—·005	1·200		
18.	−21 06	68 12	Def. N.	32 57	80	W.S.W.	1·227	—·026	—·002	1·199	1·191	
			Def. S.	34 37	80	W.S.W.	1·221	—·026	—·002	1·193		Very unsteady.
			Def. N.S.	53 10	83	W.S.W.	1·212	—·026	—·005	1·181		
19.	−21 11	67 54	Def. N.	33 12	75	N.W. by N.	1·217	—·001	—·001	1·215	1·203	
			Def. S.	34 45	76	N.W. by N.	1·215	—·001	—·001	1·213		
			Def. N.S.	53 10	75	N.W. by N.	1·212	—·001	—·004	1·207		
			wt. 1 gr.	18 00	75	N.W. by N.	1·197	—·001	+·001	1·197		
			wt. 2 grs.	37 52	75	N.W. by N.	1·183	—·001	+·001	1·183		Table steady, nearly a calm.
			wt. 2½ grs.	49 32	75	N.W. by N.	1·196	—·001	+·001	1·196		
			Def. N.	33 37	75	N.W. by N.	1·202	—·001	—·001	1·200		
			Def. S.	34 45	76	N.W. by N.	1·215	—·001	—·001	1·213		W. BURDON, Esq., R.N., observer.
			Def. N.S.	53 20	75	N.W. by N.	1·204	—·001	—·004	1·199		
20.	−21 12	67 29	Def. N.	33 25	76	W. by N.	1·200	—·013	—·001	1·186	1·201	
			Def. S.	34 45	77	W. by N.	1·215	—·013	—·001	1·201		
			Def. N.S.	53 05	79	W. by N.	1·214	—·013	—·005	1·196		Table steady.
			Def. N.	33 32	81	W. by N.	1·205	—·013	—·002	1·190		
			Def. S.	34 02	81	W. by N.	1·243	—·013	—·002	1·228		W. BURDON, Esq., R.N., observer.
			Def. N.S.	52 55	81	W. by N.	1·223	—·013	—·005	1·205		

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. May 21.	−21° 02′	66° 02′	Def. N.	33° 40′	76°	W. by N.	1·201	—·013	—·001	1·187	1·181	Table steady.
			Def. S.	34 40	76	W. by N.	1·216	—·013	—·001	1·202		
			Def. N.S.	53 15	76	W. by N.	1·201	—·013	—·004	1·184		
			wt. 1 gr.	18 22	76	W. by N.	1·175	—·013	+·001	1·163		
			wt. 2 grs.	37 37	76	W. by N.	1·191	—·013	+·001	1·179		
			wt. 2½ grs.	50 20	76	W. by N.	1·182	—·013	+·001	1·170		
23.	—20 31	59 42	Def. N.	33 47	77	W. by N.	1·194	—·013	—·001	1·180	1·171	Very unsteady.
			Def. S.	35 30	77	W. by N.	1·185	—·013	—·001	1·171		
			Def. N.S.	53 55	78	W. by N.	1·179	—·013	—·004	1·162		
27.	—20 05	57 31	Def. N.	34 58	81	Observed on shore.	1·147	....	—·002	1·145	1·156	Lieut. MOORE, R.N., observer.
	Port Louis,		Def. S.	35 52	81		1·170	....	—·002	1·168		
	Mauritius.		Def. N.S.	55 32*	81		1·115	....	—·004	1·111*		
			wt. 1 gr.	19 01	81		1·135	....	+·001	1·136		
			wt. 2 grs.	38 12	81		1·175	....	+·001	1·176		
30.	—21 44	53 34	Def. N.	33 27	80	W.S.W. ½ W.	1·208	—·024	—·002	1·182	1·179	Very unsteady.
			Def. S.	34 40	82	W.S.W. ½ W.	1·219	—·024	—·002	1·193		
			Def. N.S.	53 37	82	W.S.W. ½ W.	1·192	—·024	—·005	1·163		
June 2.	—26 25	49 12	Def. N.	34 27	79	N.W. by W.	1·168	—·005	—·002	1·161	1·160	Very unsteady.
			Def. S.	35 47	79	N.W. by W.	1·173	—·005	—·002	1·166		
			Def. N.S.	54 22	79	N.W. by W.	1·161	—·005	—·004	1·152		
4.	—27 12	46 09	Def. N.	34 45	68	W. by S.	1·156	—·024	—·001	1·131	1·129	Unsteady.
			Def. S.	36 20	68	W. by S.	1·152	—·024	—·001	1·127		
			Def. N.S.	54 30	68	W. by S.	1·155	—·024	—·001	1·130		
5.	—28 24	43 00	Def. N.	34 55	74	W.	1·150	—·020	—·001	1·129	1·125	Very unsteady.
			Def. S.	36 30	74	W.	1·145	—·020	—·001	1·124		
			Def. N.S.	54 45	76	W.	1·145	—·020	—·003	1·122		
6.	—28 44	42 01	Def. N.	35 47	73	W.N.W.	1·116	—·009	—·001	1·106	1·117	Very unsteady.
			Def. S.	36 55	76	W.N.W.	1·129	—·009	—·001	1·119		
			Def. N.S.	54 55	78	W.N.W.	1·139	—·009	—·003	1·127		
7.	—28 35	40 24	Def. N.	34 47	73	W. ½ N.	1·156	—·017	—·001	1·138	1·128	Very unsteady.
			Def. S.	36 40	74	W. ½ N.	1·138	—·017	—·001	1·120		
			Def. N.S.	54 47	74	W. ½ N.	1·145	—·017	—·003	1·125		
8.	—28 57	37 52	Def. N.	35 42	72	W.	1·120	—·020	—·001	1·099	1·094	Table steady, nearly calm.
			Def. S.	37 47	76	W.	1·095	—·020	—·001	1·074		
			Def. N.S.	55 10	78	W.	1·128	—·020	—·004	1·104		
			wt. 1 gr.	19 45	80	W.	1·100	—·020	+·002	1·082		
			wt. 2 grs.	40 30	80	W.	1·118	—·020	+·002	1·100		
			wt. 2½ grs.	53 57	82	W.	1·125	—·020	+·002	1·107		
12.	—30 33	33 19	Def. N.	36 17	66	W.N.W.	1·098	—·009	—·001	1·088	1·085	Table unsteady.
			Def. S.	37 40	66	W.N.W.	1·100	—·009	—·001	1·090		
			Def. N.S.	56 15	66	W.N.W.	1·086	—·009	—·001	1·076		
13.	—31 06	31 34	Def. N.	36 27	65	W. by S. ½ S.	1·093	—·026	—·001	1·066	1·061	Table steady.
			Def. S.	37 52	65	W. by S. ½ S.	1·093	—·026	—·001	1·066		
			Def. N.S.	56 32	67	W. by S. ½ S.	1·078	—·026	—·001	1·051		
14.	—33 01	29 36	Def. N.	36 57	71	W.	1·075	—·020	—·001	1·054	1·046	Table unsteady.
			Def. S.	38 35	72	W.	1·067	—·020	—·001	1·046		
			Def. N.S.	56 57	73	W.	1·062	—·020	—·003	1·039		
15.	—34 31	27 04	Def. N.	36 40	74	W. ½ N.	1·085	—·014	—·001	1·070	1·059	Table very unsteady, long heavy swell.
			Def. S.	38 42	76	W. ½ N.	1·063	—·014	—·001	1·048		
			Def. N.S.	56 47	78	W. ½ N.	1·067	—·014	—·004	1·049		
			wt. 1 gr.	19 47	80	W. ½ N.	1·092	—·014	+·001	1·079		
			wt. 2 grs.	45 02	80	W. ½ N.	1·027	—·014	+·001	1·014†		
			wt. 2½ grs.	58 57	82	W. ½ N.	1·063	—·014	+·001	1·050		

* Probably the degree is erroneous; the result is not included in the mean.

† Not included.

Observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Corrections.		Corrected Intensity.		Remarks.
								Ship's attraction.	Temperature.			
1845. June 16.	−35° 46′	23° 35′	Def. N.	38° 00′	75°	W. by N.	1·042	−·012	−·001	1·029	1·033	Table steady.
			Def. S.	39 17	77	W. by N.	1·043	−·012	−·001	1·030		
			Def. N.S.	57 02	78	W. by N.	1·057	−·012	−·004	1·041		
17.	−35 36	21 40	Def. N.	38 45	67	W.N.W.	1·020	−·007	−·001	1·012	1·025	Table steady.
			Def. S.	39 47	67	W.N.W.	1·026	−·007	−·001	1·018		
			Def. N.S.	57 12	67	W.N.W.	1·053	−·007	−·001	1·045		
18.	−35 07	20 46	Def. N.	38 22	64	W. by S.	1·031	−·019	·000	1·012	1·013	Table steady, nearly calm.
			Def. S.	39 50	63	W. by S.	1·024	−·019	·000	1·005		
			Def. N.S.	57 30	63	W. by S.	1·042	−·019	−·001	1·022		
23.	−34 12	18 26	Def. N.S.	57 01	62	S.	1·060	−·040	·000	1·020	1·012	Swinging ship for local attraction.
	At anchor in Simon's Bay.		Def. N.S.	57 08	66	S.S.W.	1·056	−·037	−·001	1·018		
			Def. N.S.	57 29	68	S.W.	1·042	−·031	−·001	1·010		
			Def. N.S.	57 52	68	W.S.W.	1·030	−·022	−·001	1·007		
			Def. N.S.	58 07	70	W.	1·021	−·014	−·002	1·005		
			Def. N.S.	58 11	70	W.N.W.	1·019	−·003	−·002	1·014		
			Def. N.S.	58 07	82	N.W.	1·020	−·002	−·004	1·014		
			Def. N.S.	58 16	82	N.N.W.	1·018	·000	−·004	1·014		
			Def. N.S.	58 09	83	N.	1·020	+·002	−·005	1·017		
			Def. N.S.	58 10	84	N.N.E.	1·020	·000	−·005	1·015		
			Def. N.S.	58 09	85	N.E.	1·020	−·002	−·005	1·013		
			Def. N.S.	58 07	85	E.N.E.	1·021	−·003	−·005	1·013		
			Def. N.S.	57 58	86	E.	1·026	−·014	−·005	1·007		
			Def. N.S.	57 53	87	E.S.E.	1·030	−·022	−·005	1·003		
			Def. N.S.	57 30	88	S.E.	1·042	−·031	−·006	1·005		
			Def. N.S.	57 10	90	S.S.E.	1·055	−·037	−·006	1·012		
			Def. N.S.	58 08	68	On shore.	1·021	.. ..	−·001	1·020	1·001	In the Dock Yard.
30.	−33 56	18 29	Def. N.	39 31	59	Observed on shore.	0·992	....	....	0·992		
			Def. S.	40 39	61		1·000	....	....	1·000		
			Def. N.S.	58 16	62		1·016	....	....	1·016		
			wt. 1 gr.	21 38	63		1·004	....	....	1·004		
			wt. 2 grs.	46 31	64		1·001	....	....	1·001		
			wt. 2½ grs.	65 30	65		0·999	....	....	0·999		
July 2.	Magnetic Observatory, Cape of Good Hope.		Def. N.	39 22	59		0·997	....	....	0·997		
			Def. S.	40 39	60		1·000	....	....	1·000		
			Def. N.S.	58 21	61		1·013	....	....	1·013		
			wt. 1 gr.	22 06	63		0·986	....	....	0·986		
			wt. 2 grs.	46 21	64		1·004	....	....	1·004		
			wt. 2½ grs.	65 30	64		0·999	....	....	0·999		

General Table of the DECLINATIONS observed on board Her Majesty's hired Bark "Pagoda."

Date.	Lat.	Long.	No. of observations.	Declination.	Date.	Lat.	Long.	No. of observations.	Declination.
1845. Jan. 10.	−34° 42′	17° 36′	4	+29° 51′	1845. March 28.	−36° 51′	116° 36′	3	+ 4° 31′
11.	−35 26	15 08	4	+28 39	29.	−36 10	116 43	8	+ 4 52
12.	−35 17	14 00	3	+27 15	30.	−35 12	117 41	5	+ 6 20
13.	−35 10	13 25	3	+25 40	31.	−35 28	117 04	1	+ 6 55
15.	−38 43	14 25	1	+25 09	April 11. 14.	−35 02	117 56	3	+ 5 33*
16.	−39 18	14 28	11	+28 20					
17.	−40 15	14 35	11	+27 40	21.	−35 10	118 06	1	+ 5 57
19.	−44 45	13 19	4	+26 34	22.	−35 42	115 40	1	+ 5 59
20.	−46 24	13 34	3	+25 54	23.	−35 33	114 42	3	+ 5 41
22.	−48 27	10 51	4	+24 50	24.	−34 18	113 12	4	+ 6 37
23.	−50 45	10 18	8	+23 55	25.	−32 42	111 43	5	+ 6 36
24.	−51 47	9 34	17	+23 37	26.	−30 25	109 07	4	+ 7 20
25.	−52 56	7 53	4	+23 46	27.	−29 20	106 55	2	+ 6 30
26.	−53 52	6 12	12	+21 34	28.	−27 41	106 35	2	+ 6 33
27.	−55 29	5 54	3	+21 23	29.	−26 10	105 16	3	+ 5 30
29.	−59 02	4 09	4	+17 30	30.	−24 07	102 28	2	+ 5 32
31.	−61 12	9 30	10	+20 29	May 1.	−23 58	99 21	4	+ 5 14
Feb. 1.	−62 03	12 45	4	+22 07	2.	−24 01	97 34	4	+ 7 08
2.	−61 54	16 40	8	+23 11	3.	−23 56	95 46	6	+ 6 10
3.	−61 49	19 13	27	+26 16	4.	−24 17	94 06	4	+ 5 31
4.	−62 05	20 58	9	+28 05	5.	−24 05	92 11	1	+ 6 34
5.	−63 18	21 10	6	+28 56	6.	−22 46	90 40	9	+ 5 56
6.	−64 25	25 05	9	+30 24	7.	−21 53	89 42	2	+ 4 23
7.	−65 43	28 33	11	+31 37	8.	−20 46	88 06	5	+ 4 45
9.	−66 26	37 25	3	+35 39	9.	−20 37	85 32	3	+ 5 20
10.	−66 55	38 32	5	+37 43	10.	−20 25	82 32	5	+ 5 08
11.	−67 34	39 41	7	+38 13	11.	−20 36	79 20	7	+ 4 43
12.	−66 41	39 22	3	+37 18	12.	−20 44	78 34	21	+ 5 29
13.	−67 06	40 03	5	+36 59	13.	−20 39	77 45	3	+ 5 22
14.	−67 01	40 30	2	+37 12	14.	−20 28	76 23	3	+ 6 01
16.	−64 52	38 37	5	+36 38	15.	−20 45	73 20	1	+ 5 54
17.	−64 52	40 12	6	+36 54	16.	−20 27	70 49	2	+ 6 35
18.	−64 22	40 49	2	+36 32	17.	−20 34	69 37	2	+ 6 07
19.	−63 57	41 37	3	+37 34	18.	−20 58	68 12	5	+ 8 00
20.	−63 22	45 31	6	+39 39	19.	−21 11	67 54	3	+ 6 34
21.	−63 37	47 01	7	+40 03	20.	−21 12	67 29	2	+ 7 37
22.	−63 43	49 29	2	+39 21	21.	−21 01	66 24	3	+ 7 46
25.	−61 33	53 40	6	+40 30	22.	−20 39	63 01	2	+ 8 27
26.	−61 18	57 41	6	+41 57	23.	−20 30	59 42	3	+ 9 44
27.	−61 04	63 45	4	+45 17	24.	−19 54	57 55	1	+ 9 27
28.	−61 43	69 36	1	+45 51	27.	−20 09	57 31	2	+ 9 44†
March 1.	−62 10	72 25	7	+46 01	29.	−20 50	55 32	2	+11 15
2.	−62 46	76 30	11	+50 35	30.	−21 54	53 00	4	+13 44
4.	−63 05	80 20	1	+52 17	31.	−23 44	51 48	3	+14 22
5.	−61 41	85 20	7	+47 19	June 1.	−25 47	49 40	2	+15 09
6.	−60 50	87 41	3	+47 47	2.	−26 30	49 20	3	+16 23
7.	−61 23	91 26	10	+49 28	4.	−27 12	46 02	5	+20 25
8.	−61 16	91 43	7	+49 02	5.	−28 19	43 07	3	+21 19
9.	−60 46	92 20	6	+48 01	6.	−28 49	42 07	4	+21 57
10.	−60 03	95 15	4	+44 53	7.	−28 36	40 14	5	+22 34
11.	−59 22	100 31	7	+41 02	8.	−28 57	37 49	7	+23 37
12.	−58 31	98 59	1	+39 50	9.	−30 18	35 55	2	+26 29
13.	−58 30	98 32	3	+40 37	11.	−30 30	33 42	6	+27 28
14.	−56 53	101 15	2	+37 37	12.	−30 35	33 13	1	+25 09
15.	−55 42	103 15	3	+32 54	13.	−31 09	31 31	9	+26 46
16.	−54 45	106 17	6	+29 24	14.	−32 54	29 49	4	+28 44
17.	−54 05	108 15	2	+26 34	15.	−34 44	26 50	9	+28 41
18.	−53 12	110 24	6	+21 52	16.	−35 39	23 35	5	+29 26
20.	−49 05	112 47	10	+17 09	17.	−35 40	21 37	2	+29 16
23.	−46 32	115 54	1	+12 02	18.	−35 06	20 46	1	+27 56
24.	−44 59	116 53	2	+ 9 43	19.	−35 08	20 24	2	+28 47
25.	−43 41	116 57	6	+ 7 04	20.	−34 55	19 33	3	+28 57
26.	−41 02	116 42	3	+ 4 10	23.	−34 12	18 27	16	+29 15
27.	−38 40	116 17	4	+ 6 56					

* On shore at King George's Sound.

† On shore at Port Louis, Mauritius.

General Table of the INCLINATIONS observed on board Her Majesty's hired Bark "Pagoda."

Date.	Lat.	Long.	Inclination.		Mean.
			Fox, F. 1.	Fox, C. 9.	
1844.					
November 10.	−33° 56′	18° 29′	−53° 31′	*	−53° 31′*
21.	−33 56	18 29	−53 31	*	
December 19.	−34 12	18 26	−53 50	*	−53 50†
1845.					
January 7.	−34 12	18 26	*	−53 50	
9.	−34 14	18 32	−53 39	*	−53 39
10.	−34 45	17 48	−52 56	−53 34	−53 15
11.	−35 29	15 09	*	−51 27	−51 27
12.	−35 17	14 00	*	−51 16	−51 16
13.	−35 18	13 26	−51 35	−51 18	−51 27
14.	−37 25	13 24	−51 44	*	−51 44
15.	−38 40	14 27	−52 39	−53 31	−53 05
16.	−39 10	14 40	−54 14	−54 12	−54 13
17.	−40 31	14 23	−55 10	−54 59	−55 05
18.	−42 50	13 00	−55 34	*	−55 34
19.	−44 50	13 19	−56 14	*	−56 14
21.	−49 01	11 28	−56 29	−55 34	−56 02
22.	−48 35	10 51	−56 44	*	−56 44
23.	−50 39	10 22	−57 02	−57 19	−57 11
24.	−51 49	9 33	−57 43	−57 35	−57 39
25.	−53 07	7 43	−57 03	−57 24	−57 14
26.	−53 57	6 05	−57 01	−56 58	−57 00
27.	−55 13	5 53	−57 26	−58 12	−57 49
30.	−60 43	4 00	−59 58	*	−59 58
31.	−61 10	9 05	−61 16	−61 43	−61 30
February 1.	−62 06	12 52	....	−63 17	−63 17
2.	−61 55	16 30	−63 00	−63 55	−63 28
3.	−61 50	19 14	−63 55	−64 44	−64 20
4.	−62 30	20 33	−64 55	−64 25	−64 40
5.	−63 19	21 48	*	−65 35	−65 35
6.	−64 23	24 12	−66 37	−66 41	−66 39
7.	−65 37	28 39	−66 59	−67 56	−67 28
8.	−66 27	30 45	*	−68 31	−68 31
9.	−66 33	36 48	−68 16	−69 22	−68 49
10.	−66 57	38 50	−69 22	−71 07†	−69 22
11.	−67 37	40 00	−69 49	−69 27	−69 38
12.	−67 02	39 53	−70 12	−70 20	−70 16
13.	−66 58	40 12	−69 39	−69 30	−69 35
14.	−66 24	40 01	*	−69 15	−69 15
16.	−64 52	38 37	−68 40	−68 53	−68 47
17.	−64 48	40 12	−68 44	−68 18	−68 31
18.	−64 22	40 49	−68 40	*	−68 40
19.	−63 56	41 35	−69 36	−70 02	−69 49
20.	−63 20	45 44	−70 03	−70 15	−70 09
21.	−63 36	46 46	−70 02	−70 13	−70 08
24.	−62 36	51 40	−69 13	*	−69 13
25.	−61 30	53 44	−70 46	−70 49	−70 48
26.	−61 19	57 34	−72 01	−71 27	−71 44
27.	−61 05	64 12	−73 27	−72 18	−72 53
28.	−61 43	71 08	−74 02	−73 38	−73 50
March 1.	−62 10	72 25	−74 35	−74 33	−74 34
2.	−62 44	76 12	−74 50	−75 05	−74 58
3.	−64 20	79 38	−76 34	−75 57	−76 16
5.	−61 40	84 54	−76 27	−76 58	−76 43
6.	−60 45	88 23	−75 43‡	−77 04	−77 04
7.	−61 22	91 14	−77 35	−77 41	−77 38
8.	−61 10	92 07	−78 42‡	−77 57	−77 57
9.	−60 33	92 30	−77 30	−77 33	−77 32
10.	−60 03	95 50	−77 35	−77 38	−77 37
11.	−59 52	99 40	−79 39	−79 23	−79 31
13.	−57 40	99 23	−78 36	−77 43	−78 10
14.	−56 55	101 30	−78 40	−78 11	−78 26
15.	−55 46	103 12	−78 56	−78 09	−78 33
16.	−54 43	106 10	−78 09	−79 13	−78 41
17.	−54 14	108 10	−78 49	−79 19	−79 04
1845.					
March 18.	−53° 00′	110° 22′	−77° 28′	−77° 39′	−77° 34′
19.	−51 10	111 26	−76 41	−77 36	−77 09
20.	−48 59	112 22	−76 30	−76 04	−76 17
22.	−47 21	115 15	−75 31	−75 32	−75 32
24.	−45 08	116 50	*	−73 27	−73 27
25.	−43 21	116 50	−72 45	−72 10	−72 28
26.	−41 09	116 26	−70 11	−71 14	−70 43
27.	−38 46	116 15	−68 49	−68 04	−68 27
28.	−37 02	116 57	−66 46	−66 21	−66 38
29.	−36 12	116 49	−65 28	−66 00	−65 44
30.	−35 13	117 18	−65 48	−65 24	−65 36
April 7.	−35 02	117 56	−65 11	−64 55§	−65 04‖
11.	−35 02	117 56	−65 11	−64 59¶	
12.	−35 05	117 56	*	−65 14	−65 14
20.	−35 06	117 55	*	−65 59	−65 59
23.	−35 33	114 40	−65 28	−64 54	−65 11
24.	−34 16	113 01	−64 44	*	−64 44
25.	−32 28	111 31	−62 14	−62 22	−62 18
27.	−29 18	106 52	−59 19	−59 30	−59 25
28.	−27 41	106 34	−57 17	−57 26	−57 22
29.	−25 53	105 03	−55 09	−55 05	−55 07
May 1.	−23 59	99 15	−54 28	−53 46	−54 07
2.	−24 01	97 28	−54 03	−54 18	−54 11
3.	−23 55	96 01	−54 16	−54 26	−54 21
4.	−24 17	93 50	*	−54 07	−54 07
5.	−24 02	92 07	*	−52 44	−52 44
6.	−22 47	91 00	−52 49	....	−52 49
7.	−21 47	89 41	−52 17	−51 45	−52 01
8.	−20 42	87 55	−50 57	−51 33	−51 15
9.	−20 38	85 14	−51 14	−51 21	−51 18
10.	−20 26	82 11	−51 39	−51 05	−51 22
11.	−20 36	79 16	−51 50	−51 46	−51 48
12.	−20 44	78 31	−52 03	−52 00	−52 02
13.	−20 39	77 43	−52 00	−51 58	−51 59
14.	−20 29	76 22	−52 20	*	−52 20
16.	−20 27	70 41	−52 51	−52 19	−52 35
17.	−20 34	69 24	*	−53 01	−53 01
18.	−21 07	68 08	−53 10	−53 01	−53 06
19.	−21 11	67 54	−53 02	−53 46	−53 24
20.	−21 12	67 29	−53 39	−53 59	−53 49
21.	−21 02	66 26	−54 03	−53 49	−53 56
22.	−20 40	62 58	*	−53 53	−53 53
23.	−20 31	59 42	−54 09	*	−54 09
27.	−20 09	57 31	−54 14	−53 38	−53 56**
30.	−21 47	53 30	−54 38	−54 51	−54 45
June 2.	−26 25	49 12	−58 36	*	−58 36
3.	−26 26	48 20	*	−58 46	−58 46
4.	−27 13	46 00	−58 44	−58 32	−58 38
5.	−28 13	42 50	−58 52	−58 10	−58 31
6.	−28 44	42 01	−59 01	*	−59 01
7.	−28 35	40 24	−58 54	*	−58 54
8.	−28 57	37 49	−59 08	−59 14	−59 11
11.	−30 27	33 41	*	−56 37	−56 37
12.	−30 33	33 19	−57 19	*	−57 19
13.	−31 06	31 30	−57 28	−57 24	−57 26
14.	−33 01	29 36	−57 34	*	−57 34
15.	−34 31	27 04	−57 06	*	−57 06
16.	−35 46	23 35	−56 08	*	−56 08
17.	−35 38	21 40	−55 18	−55 31	−55 25
18.	−35 07	20 46	−55 08	*	−55 08
23.	−34 12	18 26	−53 37	−53 37	−53 37
Magnetic Observatory, Cape of Good Hope, on the 2nd and 11th of July.			−53 33	−53 22	−53 29
			−53 25	−53 27	
				−53 37	

* Magnetic Observatory, Cape of Good Hope.

† Dock Yard, Simon's Bay.

‡ Probably a wrong degree; omitted in the mean.

§ Needle A.

¶ Needle B.

‖ King George's Sound.

** Port Louis, Mauritius.

General Table of the INTENSITIES of the MAGNETIC FORCE observed on board Her Majesty's hired Bark "Pagoda."

Date.	Lat.	Long.	Intensity.		Mean.
			Fox, F. 1.	Fox, C. 9.	
1844.					
Dec. 1 and 5.	−33° 56′	18° 29′	0·999*	....	0·999
21.	−34 12	18 26	1·005†	....	1·005
1845.					
January 10.	−34 45	17 48	0·981	0·985	0·983
11.	−35 29	15 09	....	0·968	0·968
12.	−35 17	14 00	....	0·923	0·923
13.	−35 18	13 26	0·950	0·933	0·942
14.	−37 25	13 24	0·965	....	0·965
15.	−38 40	14 27	1·008	0·978	0·993
16.	−39 10	14 40	0·989	0·964	0·977
17.	−40 31	14 23	0·994	0·984	0·989
18.	−42 50	13 00	0·997	....	0·997
19.	−44 50	13 19	1·007	....	1·007
21.	−49 01	11 28	1·051	1·051	1·051
22.	−48 35	10 51	1·060	....	1·060
23.	−50 39	10 22	1·094	1·093	1·094
24.	−51 49	9 33	1·120	1·109	1·115
25.	−53 07	7 43	1·122	1·134	1·128
26.	−53 57	6 05	1·143	1·141	1·142
27.	−55 13	5 53	1·161	1·143	1·152
30.	−60 43	4 00	1·240	....	1·240
31.	−61 10	9 05	1·285	1·288	1·287
February 1.	−62 06	12 52	....	1·349	1·349
2.	−61 55	16 30	1·331	1·321	1·326
3.	−61 50	19 14	1·334	....	1·334
4.	−62 30	20 33	1·353	1·347	1·350
5.	−63 19	21 48	....	1·362	1·362
6.	−64 23	24 12	1·401	1·398	1·400
7.	−65 37	28 39	1·432	1·432	1·432
8.	−66 27	30 45	....	1·448	1·448
9.	−66 33	36 48	1·482	1·470	1·476
10.	−66 57	38 50	1·491	1·483	1·487
11.	−67 37	40 00	1·519	1·496	1·508
12.	−67 02	39 53	1·494	1·496	1·495
13.	−66 58	40 12	1·499	1·490	1·495
14.	−66 24	40 01	....	1·494	1·494
16.	−64 52	38 37	1·470	1·450	1·460
17.	−64 48	40 12	1·463	1·482	1·473
18.	−64 22	40 49	1·460	....	1·460
19.	−63 56	41 35	1·416	1·453	1·434
20.	−63 20	45 44	1·437	1·462	1·450
21.	−63 36	46 46	1·457	1·470	1·464
24.	−62 36	51 40	1·466	....	1·466
25.	−61 30	53 44	1·476	1·498	1·487
26.	−61 19	57 34	1·535	1·506	1·521
27.	−61 05	64 12	1·553	1·560	1·557
28.	−61 43	71 08	1·604	1·605	1·605
March 1.	−62 10	72 25	1·657	1·642	1·650
2.	−62 44	76 12	1·656	1·653	1·655
3.	−64 20	79 38	1·706	1·678	1·692
5.	−61 40	84 54	1·689	1·730	1·710
6.	−60 45	88 23	1·729	1·747	1·738
7.	−61 22	91 14	1·759	1·749	1·754
8.	−61 10	92 07	1·762	1·758	1·760
9.	−60 33	92 30	1·745	1·750	1·748
10.	−60 03	95 50	1·798	1·770	1·784
11.	−59 52	99 40	1·772	1·836	1·804
13.	−57 40	99 23	1·968‡	1·813	1·813
14.	−56 55	101 30	1·786	1·802	1·794
15.	−55 46	103 12	1·816	1·815	1·816
16.	−54 43	106 10	1·801	1·817	1·809
17.	−54 14	108 10	1·816	1·821	1·819
18.	−53 00	110 22	1·814	1·825	1·820

Date.	Lat.	Long.	Intensity.		Mean.
			Fox, F. 1.	Fox, C. 9.	
1845.					
March 19.	−51° 10′	111° 26′	1·787	....	1·787
20.	−48 59	112 22	1·798	1·821	1·810
22.	−47 21	115 15	1·825	1·842	1·834
24.	−45 08	116 50	....	1·820	1·820
25.	−43 21	116 50	1·760	1·804	1·782
26.	−41 09	116 26	1·746	1·758	1·752
27.	−38 46	116 15	1·738	1·722	1·730
28.	−37 02	116 57	1·695	1·677	1·686
29.	−36 12	116 49	1·673	1·670	1·672
30.	−35 13	117 18	1·702	1·694	1·698
April 7.	−35 02	117 56	1·688	1·688	1·688§
11.	−35 02	117 56	1·688	....	
12.	−35 05	117 56	....	1·688	
23.	−35 33	114 40	1·688	1·672	1·680
24.	−34 16	113 01	1·641	....	1·641
25.	−32 28	111 31	1·613	1·573	1·593
27.	−29 18	106 52	1·553	1·499	1·526
28.	−27 41	106 34	1·490	1·478	1·484
29.	−25 53	105 03	1·470	1·447	1·459
May 1.	−23 59	99 15	1·367	1·381	1·374
2.	−24 01	97 28	1·379	1·381	1·380
3.	−23 55	96 01	1·365	1·377	1·371
4.	−24 17	93 50	....	1·352	1·352
5.	−24 02	92 07	....	1·367	1·367
6.	−22 47	91 00	1·324	....	1·324
7.	−21 47	89 41	1·326	1·314	1·320
8.	−20 42	87 55	1·294	1·298	1·296
9.	−20 38	85 14	1·265	1·263	1·264
10.	−20 26	82 11	1·257	1·248	1·253
11.	−20 36	79 16	1·247	1·213	1·230
12.	−20 44	78 31	1·238	1·234	1·236
13.	−20 39	77 43	1·237	1·233	1·235
14.	−20 29	76 22	1·222	....	1·222
16.	−20 27	70 41	1·199	1·205	1·202
17.	−20 34	69 24	....	1·210	1·210
18.	−21 07	68 08	1·191	....	1·191
19.	−21 11	67 54	1·203	1·206	1·205
20.	−21 12	67 29	1·201	1·190	1·196
21.	−21 02	66 26	1·181	1·178	1·180
22.	−20 40	62 58	....	1·173	1·173
23.	−20 31	59 42	1·171	....	1·171
27.	−20 09	57 31	1·156	1·156	1·156‖
30.	−21 47	53 30	1·179	1·161	1·170
June 2.	−26 25	49 12	1·160	....	1·160
3.	−26 26	48 20	....	1·164	1·164
4.	−27 13	46 00	1·129	1·159	1·144
5.	−28 13	42 50	1·125	....	1·125
6.	−28 44	42 01	1·117	....	1·117
7.	−28 35	40 24	1·128	....	1·128
8.	−28 57	37 49	1·094	1·111	1·103
11.	−30 27	33 41	....	1·105	1·105
12.	−30 33	33 19	1·085	....	1·085
13.	−31 06	31 30	1·061	1·063	1·062
14.	−33 01	29 36	1·046	....	1·046
15.	−34 31	27 04	1·059	....	1·059
16.	−35 46	23 35	1·033	....	1·033
17.	−35 38	21 40	1·025	1·033	1·029
18.	−35 07	20 46	1·013	....	1·013
23.	−34 12	18 26	1·012	1·001	1·007¶
Magnetic Observatory, Cape of Good Hope, 2nd and 11th of July.			1·001	1·000	1·000

* Observed on shore, Magnetic Observatory, Cape of Good Hope.

† Observed on shore, Dock-yard, Simon's Bay.

‡ Not included in the mean.

§ King George's Sound; observed on shore.

‖ Port Louis, Mauritius; observed on shore.

¶ Simon's Bay, on board.

Observations of the Magnetic Inclination between the Cape of Good Hope and Van Diemen Island, by Lieut. Alexander Smith, R.N.

Date.	Lat.	Long.	Corrected Inclination.	Date.	Lat.	Long.	Corrected Inclination.
1844.				1844.			
July 29.	−38° 00′	4° 20′	−52° 00′	Aug. 20.	−38° 25′	76° 44′	−66° 54′
30.	−38 28	7 45	−53 03	21.	−38 48	77 50	−67 14
31.	−39 06	12 00	−55 42	22.	−39 04	79 45	−67 17
August 1.	−39 42	15 44	−57 06	23.	−39 58	84 00	−67 43
2.	−39 33	23 05	−59 32	24.	−40 06	87 00	−68 13
4.	−39 33	26 52	−61 47	25.	−40 06	90 52	−68 41
5.	−39 50	28 36	−62 08	26.	−40 02	95 10	−69 08
6.	−40 01	32 22	−62 56	27.	−39 52	99 22	−69 00
7.	−40 32	36 40	−64 09	28.	−39 54	102 00	−69 00
8.	−41 06	41 40	−64 42	29.	−40 08	105 55	−69 22
9.	−41 00	46 13	−65 19	30.	−40 31	109 06	−70 02
10.	−40 43	49 12	−66 08	31.	−41 16	113 25	−70 30
11.	−40 56	53 30	−66 25	Sept. 1.	−41 54	117 40	−71 20
13.	−39 34	60 55	−67 27	1.	−41 58	119 00	−71 33
14.	....	......	−67 18	2.	−42 17	122 30	−71 45
15.	−39 00	65 44	−67 19	3.	−42 35	125 40	−72 08
16.	−38 31	68 45	−66 45	4.	−43 00	129 36	−72 08
17.	−38 22	70 10	−67 06	5.	−43 16	133 44	−72 13
18.	−38 08	73 35	−66 45	6.	−43 28	137 10	−71 55
19.	−38 10	75 22	−66 42	7.	−44 06	141 37	−72 14

Observations of the Magnetic Force between the Cape of Good Hope and Van Diemen Island, by Lieut. Alexander Smith, R.N.

Date.	Lat.	Long.	Method employed.	Angle of deflection.	Thermometer.	Ship's head.	Intensity. Hobarton = 1·800.		Remarks.
1844.									
July 30.	−38° 28′	27° 45′	wt. 2 grs.	20° 13′	52°	S.E. ½ E.	0·953	0·953	
Aug. 5.	−39 50	28 36	wt. 2 grs.	17 04	60	S.E. by E.	1·121	1·117	
	−39 50	28 36	wt. 3 grs.	26 35	59	S.E. by E.	1·113		
9.	−41 00	46 13	wt. 2 grs.	14 50	60	E. ½ S.	1·288	1·288	
	−41 00	46 13	wt. 3 grs.	22 46	61	E. ½ S.	1·289		
15.	−39 00	65 44	wt. 2 grs.	13 35	47	S.E. by E.	1·403	1·383	Much motion.
	−39 00	65 44	wt. 3 grs.	21 26	44	S.E. by E.	1·364		
18.	−38 08	73 35	wt. 2 grs.	12 57	58	E.	1·471	1·454	Smooth water.
	−38 08	73 35	wt. 3 grs.	20 18	59	E.	1·437		
19.	−38 10	75 22	wt. 2 grs.	13 28	66	S.E. ½ E.	1·415	1·435	Smooth.
	−38 10	75 22	wt. 3 grs.	20 02	66	S.E. ½ E.	1·456		
24.	−40 06	87 00	wt. 2 grs.	12 14	64	E.S.E.	1·555	1·597	
	−40 06	87 00	wt. 3 grs.	17 42	60	E.S.E.	1·640		
28.	−39 54	102 00	wt. 2 grs.	11 13	51	E.S.E.	1·694	1·724	
	−39 54	102 00	wt. 3 grs.	16 31	51	E.S.E.	1·754		
30.	−40 31	109 06	wt. 2 grs.	11 04	58	E.S.E.	1·717	1·751	
	−40 31	109 06	wt. 3 grs.	16 14	59	E.S.E.	1·785		
Sept 3.	−42 35	125 40	wt. 2 grs.	10 04	56	E. by S.	1·886	1·894	
	−42 35	125 40	wt. 3 grs.	15 12	55	E. by S.	1·902		
5.	−43 14	133 22	wt. 2 grs.	10 21	49	E. by S.	1·834	1·869	
	−43 14	133 22	wt. 3 grs.	15 11	48	E. by S.	1·904		
6.	−43 28	137 10	wt. 2 grs.	10 06	51	E. ½ S.	1·879	1·866	
	−43 28	137 10	wt. 3 grs.	15 36	51	E. ½ S.	1·854		
Oct. 2.	−42 52	147 24	wt. 2 grs.	10 33	54	On shore.	1·800	1·800	Hobarton: Magnetic Observatory.
	−42 52	147 24	wt. 3 grs.	16 05	54		1·800		

Hobarton is taken as the base station; no correction has been applied for the effect of the ship's iron. In the results entered in the map of the Magnetic Force from Lieut. Smith's observations on the 24th, 28th, and 30th of August, the determinations with 2 grains only have been used; those with 3 grains are so discordant with other results as necessarily to indicate an error in them.

Observations of the Magnetic Inclination between Van Diemen Island and the Cape of Good Hope, by Lieut. Joseph Dayman, R.N.

Date.	Lat.	Long.	Corrected Inclination.
1844.	° ′	° ′	° ′
Dec. 6.	Hobarton Observatory.		−70 40
16.	−44 48	144 51	−71 36
17.	−44 30	143 56	−70 50
18.	−44 34	142 51	−71 31
19.	−44 34	139 37	−73 11
20.	−43 21	138 37	−70 33
21.	−42 24	137 18	−70 42
23.	−41 46	133 26	−70 40
24.	−42 02	131 31	−72 03?
26.	−41 24	129 30	−70 22
27.	−42 08	128 45	−71 11
28.	−40 05	128 23	−70 08
30.	−39 25	124 04	−69 40
31.	−38 00	123 38	−68 21
1845.			
Jan. 1.	−38 21	122 46	−67 27
2.	−37 52	122 29	−67 39
3.	−37 14	121 58	−67 07
4.	−37 13	120 40	−68 06
6.	−36 28	118 57	−67 08
7.	−35 22	117 46	−65 53
9.	−36 42	118 35	−67 03
10.	−36 58	117 38	−67 19
11.	−36 06	116 42	−66 27
13.	−36 24	115 33	−66 44
14.	−37 00	115 10	−66 35
15.	−35 46	114 14	−65 48
16.	−34 58	112 59	−65 16
17.	−33 47	111 04	−63 23
18.	−32 37	108 24	−62 18
20.	−29 40	105 28	−59 37
21.	−28 04	105 06	−58 33
22.	−26 44	104 26	−56 54
23.	−25 52	102 58	−55 50
24.	−24 50	101 31	−54 44
1845.	° ′	° ′	° ′
Jan. 25.	−24 00	99 33	−54 20
27.	−23 11	95 40	−53 44
28.	−22 54	93 48	−53 26
29.	−22 19	91 16	−53 11
30.	−22 17	89 57	−53 11
31.	−22 11	86 30	−53 20
Feb. 1.	−22 08	84 17	−53 52
3.	−22 34	80 10	−54 23
4.	−22 35	78 08	−54 26
5.	−22 38	76 10	−54 45
6.	−22 28	74 18	−54 41
7.	−22 33	72 00	−55 04
8.	−22 41	69 54	−55 54
10.	−23 52	64 59	−56 52
11.	−24 23	62 54	−57 57
12.	−24 50	61 11	−58 15
13.	−24 43	59 46	−57 59
14.	−24 36	58 37	−58 17
15.	−24 45	57 03	−59 13
17.	−25 13	51 29	−58 34
18.	−25 42	49 06	−58 43
19.	−26 54	45 47	−58 41
20.	−28 15	42 18	−59 37
21.	−29 21	39 06	−60 01
22.	−30 10	36 17	−59 08
24.	−31 19	32 21	−58 32
25.	−32 17	29 34	−58 16
26.	−34 02	26 53	−57 23
27.	−34 35	25 31	−56 45
28.	−34 36	25 23	−56 35
March 1.	−34 40	24 16	−56 32
3.	−34 04	22 45	−56 43
4.	−34 29	21 44	−55 36
5.	−34 48	19 33	−54 50

Observations of the Magnetic Force between Van Diemen Island and the Cape of Good Hope, by Lieut. Joseph Dayman, R.N.

Date.	Lat.	Long.	Weights.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity. Hobarton =1·800.	Remarks.
1844.			grs.							
Dec. 6.	−42° 52′	147° 24′	2	10° 43′	71°	On shore.	1·800	········	1·800	Magnetic Observatory, Hobarton.
	−42 52	147 24	3	16 11	71		1·800			
16.	−44 48	144 51	2	10 21	55	w. by s.	1·863	−·041	1·827	
	−44 48	144 51	3	15 32	55	w. by s.	1·873			
17.	−44 30	143 56	2	10 31	67	w. by s.	1·834	−·041	1·815	
	−44 30	143 56	3	15 29	67	w. by s.	1·879			
18.	−44 34	142 51	2	10 20	69	w. by s.	1·866	−·041	1·818	
	−44 34	142 51	3	15 44	70	w. by s.	1·851			
19.	−44 34	139 37	3	15 18	63	s.w. by s.	1·901	−·053	1·848	
21.	−42 24	137 18	2	10 29	69	w.	1·840	−·037	1·828	
	−42 24	137 18	3	15 24	70	w.	1·889			
23.	−41 46	133 26	2	10 32	58	N.	1·831	−·020	1·846	
	−41 46	133 26	3	15 18	57	N.	1·901			
28.	−40 05	128 23	2	10 05	63	N.W. by N.	1·912	−·020	1·856	A long heavy swell.
	−40 05	128 23	3	15 49	63	N.W. by N.	1·840			
30.	−39 25	124 04	2	10 38	65	N. by W.	1·814	−·020	1·793	A long heavy swell.
	−39 25	124 04	3	16 04	65	N. by W.	1·813			
31.	−38 00	123 38	2	10 25	62	N.N.W.	1·852	−·020	1·799	A long heavy swell.
	−38 00	123 38	3	16 19	62	N.N.W.	1·786			
1845.										
Jan. 1.	−38 21	122 46	2	10 49	71	N.W. by W.	1·783	−·025	1·777	
	−38 21	122 46	3	15 59	72	N.W. by W.	1·822			
3.	−37 14	124 58	2	10 55	69	N.W.	1·767	−·020	1·771	
	−37 14	124 58	3	16 03	69	N.W.	1·815			
6.	−36 28	118 57	2	11 11	67	N.N.W.	1·725	−·020	1·716	
	−36 28	118 57	3	16 41	67	N.N.W.	1·747			
7.	−35 22	117 46	2	11 04	65	N.N.W. ½ W.	1·743	−·020	1·722	
	−35 22	117 46	3	16 44	64	N.N.W. ½ W.	1·742			
11.	−36 06	116 42	2	10 55	68	S.S.W.	1·767	−·055	1·715	
	−36 06	116 42	3	16 26	68	S.S.W.	1·773			
16.	−34 58	112 59	2	11 24	66	N.W.	1·693	−·012	1·686	
	−34 58	112 59	3	17 07	66	N.W.	1·704			
17.	−33 47	111 04	2	11 54	67	N.W. by W.	1·623	−·017	1·609	
	−33 47	111 04	3	17 53	67	N.W. by W.	1·629			
18.	−33 37	108 24	2	11 57	69	N.W. by W.	1·616	−·017	1·603	
	−33 37	108 24	3	17 59	69	N.W. by W.	1·624			
20.	−29 40	105 28	2	12 30	72	N.W. ½ N.	1·546	−·007	1·537	
	−29 40	105 28	3	18 58	72	N.W. ½ N.	1·543			
21.	−28 04	105 06	2	13 02	73	N.	1·484	−·004	1·493	
	−28 04	105 06	3	19 24	73	N.	1·510			
22.	−26 44	104 26	2	13 03	76	N.W.	1·483	−·007	1·466	
	−26 44	104 26	3	20 05	76	N.W.	1·462			
23.	−25 52	102 58	2	13 39	75	N.W.	1·418	−·007	1·421	
	−25 52	102 58	3	20 24	75	N.W.	1·439			
24.	−24 50	101 31	2	13 31	76	N.W.	1·432	−·006	1·415	
	−24 50	101 31	3	20 51	76	N.W.	1·410			
25.	−24 00	99 33	2	13 30	75	W.N.W.	1·435	−·010	1·407	
	−24 00	99 33	3	21 02	75	W.N.W.	1·400			
27.	−23 11	95 40	2	14 22	78	W. by N. ½ N.	1·350	−·012	1·334	
	−23 11	95 40	3	21 58	78	W. by N. ½ N.	1·342			
28.	−22 54	93 48	2	14 16	78	W. by N. ½ N.	1·360	−·012	1·337	
	−22 54	93 48	3	22 03	79	W. by N. ½ N.	1·338			
29.	−22 19	91 16	2	15 02	77	W. ½ N.	1·291	−·017	1·277	
	−22 19	91 16	3	22 46	77	W. ½ N.	1·297			
30.	−22 17	89 57	2	14 58	80	W. ½ N.	1·296	−·017	1·288	
	−22 17	89 57	3	22 28	81	W. ½ N.	1·314			
31.	−22 11	86 30	2	15 11	80	W. ½ N.	1·278	−·017	1·274	
	−22 11	86 30	3	22 38	80	W. ½ N.	1·304			

Lieut. Dayman's observations of the Magnetic Force. (Continued.)

Date.	Lat.	Long.	Weights.	Angle of deflection.	Thermometer.	Ship's head.	Intensity.	Correction for ship's attraction.	Corrected Intensity. Hobarton = 1·800.	Remarks.
1845.	° ′	° ′	grs.	° ′	°					
Feb. 1.	−22 08	84 17	2	15 13	81	w. ½ n.	1·275	−·017	1·251	
	−22 08	84 17	3	23 25	81	w. ½ n.	1·262			
3.	−22 34	80 10	2	15 16	83	w. ¼ n.	1·272	−·019	1·261	
	−22 34	80 10	3	22 55	83	w. ¼ n.	1·288			
4.	−22 35	78 08	2	15 42	83	w. ¾ n.	1·237	−·015	1·237	
	−22 35	78 08	3	23 20	83	w. ¾ n.	1·267			
5.	−22 38	76 10	2	15 31	82	w. ¾ n.	1·252	−·015	1·236	
	−22 38	76 10	3	23 41	82	w. ¾ n.	1·250			
6.	−22 28	74 18	2	15 50	82	w. ¾ n.	1·227	−·015	1·216	
	−22 28	74 18	3	23 58	82	w. ¾ n.	1·236			
7.	−22 33	72 20	2	15 49	81	w. ½ n.	1·229	−·016	1·211	
	−22 33	72 20	3	24 11	81	w. ½ n.	1·225			
8.	−22 41	69 54	2	15 38	81	w.	1·240	−·018	1·215	
	−22 41	69 54	3	24 13	81	w.	1·223			
10.	−23 52	64 59	2	15 58	84	w. ½ s.	1·217	−·022	1·196	
	−23 52	64 59	3	24 20	84	w. ½ s.	1·218			
11.	−24 23	62 54	2	16 13	83	w. ½ s.	1·199	−·022	1·177	
	−24 23	62 54	3	24 44	83	w. ½ s.	1·199			
12.	−24 50	61 11	2	16 01	84	w. ½ n.	1·214	−·018	1·197	
	−24 50	61 11	3	24 22	84	w. ½ n.	1·216			
13.	−24 43	59 46	2	16 17	85	w. by n. ½ n.	1·194	−·011	1·184	
	−24 43	59 46	3	24 47	85	w. by n. ½ n.	1·197			
14.	−24 36	58 37	2	16 23	85	w. by n. ½ n.	1·187	−·011	1·178	
	−24 36	58 37	3	24 55	84	w. by n. ½ n.	1·191			
17.	−25 13	51 29	2	16 46	84	w. ½ n.	1·160	−·017	1·139	
	−25 13	51 29	3	25 49	84	w. ½ n.	1·152			
18.	−25 42	49 06	2	17 09	82	w.	1·135	−·020	1·114	
	−25 42	49 06	3	26 16	81	w.	1·133			
20.	−28 15	42 18	2	17 43	81	w. ½ s.	1·100	−·022	1·086	
	−28 15	42 18	3	26 44	81	w. ½ s.	1·116			
21.	−29 21	39 06	2	17 46	81	w.	1·097	−·020	1·081	
	−29 21	39 06	3	26 59	81	w.	1·106			
22.	−30 10	36 17	2	17 55	82	w. ¼ n.	1·088	−·018	1·076	
	−30 10	36 17	3	27 07	82	w. ¼ n.	1·101			
24.	−31 19	32 21	2	18 29	83	w. ½ n.	1·056	−·016	1·046	
	−31 19	32 21	3	28 01	83	w. ½ n.	1·068			
25.	−32 17	29 34	2	18 59	82	w. ¾ n.	1·029	−·014	1·026	
	−32 17	29 34	3	28 28	82	w. ¾ n.	1·052			
26.	−34 02	26 53	2	18 57	74	w.	1·030	−·018	1·012	
	−34 02	26 53	3	28 37	74	s.w.	1·047	−·035		
28.	−34 36	25 23	2	18 38	71	s.w. ½ w.	1·047	−·030	1·021	
	−34 36	25 23	3	28 22	71	s.w. ½ w.	1·056			
Mar. 1.	−34 40	24 16	2	19 27	79	w.n.w.	1·005	−·007	1·004	
	−34 40	24 16	3	29 35	79	w.n.w.	1·016			
5.	−34 48	19 33	2	19 51	71	n.w. ½ n.	0·986	·000	0·984	
	−34 48	19 33	3	30 46	70	n.w. ½ n.	0·981			

Observations of the Magnetic Declination, made on board Her Majesty's Ship Erebus, by Captain Sir James Clark Ross, between the Cape of Good Hope and Van Diemen Island.

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Remarks.
1840.	° ′	° ′		° ′		° ′	° ′	° ′	° ′	
April 8.	−35 52	18 41	T.	+28 28	W.	−53 30	+2 05	+30 33	+30 08	Compass C. H. used in all the following observations; no index error.
			T.	+31 52	E.S.E.		−2 13	+29 39		
			O.	+31 50	E.S.E.		−2 13	+29 37		
			T.	+32 13	S.E. by E.		−2 07	+30 06		
			S.	+30 44	S.		0 00	+30 44		
	−36 11	18 35	R.	+31 50	S.E. ½ S.	−53 40	−1 45	+30 05	+30 05	
10.	−36 20	20 28	T.	+31 39	S.E. ½ S.	−55 00	−1 48	+29 51	+30 15	
	−36 12	20 55	T.	+32 02	S.S.E. ½ E.		−1 23	+30 39		
11.	−36 21	21 14	S.	+30 03	S.W.	−55 30	+2 00	+32 03	+30 40	
			O.	+30 41	S. by W.		+0 37	+31 18		
			T.	+29 56	S. by W.		+0 37	+30 33		
			T.	+30 26	S.		0 00	+30 26		
			S.	+30 17	S.		0 00	+30 17		
	−36 28	21 15	T.	+30 20	S.		0 00	+30 20		
			R.	+30 14	S.		0 00	+30 14		
			T.	+30 19	S. ½ E.		−0 19	+30 00		
			O.	+31 00	S. ½ E.		−0 19	+30 41		
			S.	+30 41	S. ½ E.		−0 19	+30 22		
			T.	+31 11	S. ½ E.		−0 19	+30 52		
			R.	+31 29	S.		0 00	+31 29		
			T.	+31 02	S. ½ E.		−0 19	+30 43		
			R.	+30 01	S.		0 00	+30 01		
12.	−37 10	21 31	T.	+31 53	S. ½ W.	−56 00	+0 19	+32 12	+30 51	
			T.	+32 09	S. ½ E.		−0 19	+31 50		
			T.	+32 10	S. by E.		−0 38	+31 32		
			T.	+31 50	S. by E.		−0 38	+31 12		
			O.	+31 09	S. by E.		−0 38	+30 31		
			S.	+31 16	S. by E.		−0 38	+30 38		
			T.	+31 14	S. by E.		−0 38	+30 36		
	−37 27	21 20	R.	+28 57	S. by E.		−0 38	+28 19		
13.	−38 11	21 27	S.	+32 43	S.E. ½ E.	−57 30	−2 16	+30 27	+32 10	
	−38 20	21 12	T.	+31 10	S.W. by W.		+2 23	+33 33		
			T.	+30 04	S.W.		+2 09	+32 13		
			T.	+30 20	S.W.		+2 09	+32 29		
14.	−39 55	20 35	T.	+29 51	S.S.W.	−59 30	+1 18	+31 09	+31 09	
15.	−41 00	22 01	T.	+32 30	S.E. by S.	−59 40	−2 04	+30 26	+29 51	
	−41 15	22 22	S.	+31 20	S.E. by S.		−2 04	+29 16		
16.	−41 24	24 32	T.	+32 09	S.S.E. ½ E.	−62 00	−1 46	+30 23	+30 25	
			T.	+32 35	S.E. ½ S.		−2 17	+30 18		
			S.	+31 00	S.E. by S.		−2 03	+28 57		
	−41 32	25 31	T.	+32 45	S.S.E. ½ E.		−1 46	+30 59		
			R.	+32 41	S.S.E.		−1 24	+31 17		
	−41 28	25 39	R.	+32 00	S.S E.		−1 24	+30 36		
17.	−41 50	26 24	S.	+31 48	S.S.E.	−62 10	−1 26	+30 22	+31 49	
			T.	+34 43	S.S.E.		−1 26	+33 17		
18.	−42 54	28 13	T.	+34 27	S.S.E.	−62 30	−1 26	+33 01	+33 37	
			S.	+34 43	S.S.E.		−1 26	+33 17		
			O.	+35 58	S.S.E.		−1 26	+34 32		
	−43 24	29 19	R.	+33 58	S.S.E.	−62 40	−1 26	+32 32	+32 43	
			T.	+33 39	S. by E.		−0 45	+32 54		
25.	−46 31	48 03	R.	+35 44	S.E.	−67 00	−3 03	+32 41	+32 41	
28.	−46 34	52 43	T.	+31 44	N.W.	−67 30	+2 12	+33 56	+33 28	
			T.	+31 53	N.N.W.		+1 07	+33 00		

Observations of Declination. (Continued.)

Date.	Lat.	Long.	Observer.	Declination observed.	Ship's head.	Inclination.	Correction for ship's attraction.	Corrected Declination.		Remarks.
1840. April 30.	−46° 32′	52° 01′	T.	+31° 40′	N. by E. ½ E.	−67° 30′	+0° 53′	+32° 33′	+33° 16′	
May 1.	−46 32	52 01	R.	+37 06	S.E.	−67 30	−3 07	+33 59		
2.	−47 03	56 17	S.	+36 34	S.E.	−67 50	−3 07	+33 27	+31 32	
			T.	+33 48	S.E.		−3 07	+30 41		
		56 28	R.	+33 34	S.E.		−3 07	+30 27		
4.	−47 45	62 27	T.	+32 21	S.E.	−68 30	−3 15	+29 06	+29 00	
			S.	+32 10	S.E.		−3 15	+28 55		
July 27.	−47 18	93 36	R.	+30 00	S.E. by E. ½ E.	−72 30	−4 41	+25 38		
			R.	+31 50	S.E. by E. ½ E.					
			R.	+30 32	S.E. by E. ½ E.					
			R.	+29 39	S.E. by E. ½ E.					
			R.	+29 34	S.E. by E. ½ E.					
31.	−47 34	105 47	T.	+24 09	S.E. by E. ½ E.	−74 10	−5 10	+18 59		
Aug. 2.	−47 45	113 49	T.	+16 39	E. by S. ½ S.	−75 10	−5 49	+11 29		
			T.	+17 58	E. by S. ½ S.					
4.	−47 40	121 50	R.	+15 26	E. ½ S.	−75 30	−5 51	+ 9 34		
			R.	+15 11	E. ½ S.					
			R.	+15 39	E. ½ S.					
7.	−46 36	131 48	T.	+ 1 58	E. ½ N.	−75 00	−5 35		− 1 00	
			T.	+ 3 44	E. by N.		−5 27			
			T.	+ 3 08	E. ½ N.		−5 35			
			T.	+ 5 43	E. ½ N.		−5 35			
			R.	+ 5 58	E.		−5 43			
			R.	+ 6 30	E.		−5 43			
			R.	+ 4 29	E.		−5 43			
			R.	+ 5 16	E.		−5 43			
	−46 13	132 00	R.	+ 2 09	E.	−75 00	−5 43		− 0 34	
	−46 06	132 12	R.	+ 6 17	E. ½ N.		−5 35			
			R.	+ 6 53	E. ½ N.		−5 35			
			R.	+ 7 25	E. ½ N.		−5 35			
			R.	− 3 06	N.		0 00			
10.	−44 23	141 11	T.	− 4 19	E.N.E.	−73 00	−4 20	− 7 52		
			R.	− 3 12	E.N.E.					
			T.	− 3 12	E.N.E.					
			R.	− 4 01	E.N.E.					
			T.	− 3 39	E.N.E.					
			R.	− 4 24	E.N.E.					
			T.	− 2 01	E.N.E.					

The observers are distinguished by their initials as follows:—

R., Sir James Ross; S., Lieut. Sibbald; T., Mr. Tucker, Master; O., Mr. Oakley, Mate.

Observations of the Magnetic INCLINATION taken on board Her Majesty's Ship Erebus, by Captain Sir JAMES CLARK Ross, with Needle F. 1., between the Cape of Good Hope and Kerguelen Island.

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1840.	° ′	° ′		° ′		′	′	° ′	
April 7.	−35 14	18 27	Direct.	−54 23	S. by E.	−04	−2·0	−54 32	
			S.	−54 30					
8.	−35 48	18 47	Direct.	−54 34	E.S.E.	+23	−2·0	−54 18	
			S.	−54 39					
			Direct.	−54 38	W. by S.				
			S.	−54 47					
9.	−36 00	19 00	Direct.	−55 42		+34	−2·0	−55 24	
			S.	−56 10					
10.	−36 07	20 55	Direct.	−55 49	S.E. by S.	+02	−2·0	−55 50	
			S.	−55 51					
11.	−36 29	21 16	Direct.	−55 30	S.	−10	−2·0	−55 38	
			S.	−55 36					
			S.N.	−55 26					
			N.	−55 14					
12.	−37 19	21 37	Direct.	−55 27	S.	−10	−2·0	−56 03	
			S.	−56 01					
			Direct.	−55 42					
			S.	−56 11					
			Direct.	−55 56					
13.	−38 11	22 00	Direct.	−55 41	W.S.W.	+22	−2·0	−55 35	Much motion.
			S.	−56 09					
14.	−40 05	20 38	Direct.	−56 27	S.S.E.	−08	−2·0	−56 33	
			S.	−56 19					
15.	−40 29	22 22	Direct.	−57 13	S.E. by S.	−06	−2·0	−57 28	
			S.	−57 28					
16.	−41 24	25 00	Direct.	−58 00	S.E. by S.	−08	−2·0	−58 21	
			S.	−58 24					
			S.N.	−58 11					
			N.	−58 11					
17.	−41 47	26 38	Direct.	−58 22	S.S.E.	−15	−2·0	−58 43	
			S.	−58 31					
18.	−43 02	28 36	Direct.	−59 01	S.S.E.	−19	−2·0	−59 31	
			S.	−59 20					
	−43 07	28 43	S.N.	−59 20		−20	−2·0	−59 37	
			N.	−59 21					
			Direct.	−59 05					
19.	−44 19	31 06	Direct.	−60 30	S. by E.	−29	−2·0	−60 52	
			S.	−60 13					
20.	−45 40	34 08	Direct.	−61 41	S.S.E.	−30	−2·0	−62 23	
			S.	−62 01					
21.	−46 59	37 14	Direct.	−63 28	S.E. by S.	−28	−2·0	−64 00	
			S.	−63 32					
22.	−47 00	38 14	Direct.	−63 52	S.E. by S.	−29	−2·0	−64 30	
			S.	−64 06					
23.	−46 46	42 23	Direct.	−64 59	S.E. by S.	−32	−2·0	−65 47	Much motion.
			S.	−65 32					
			Direct.	−65 09					
24.	−47 01	46 10	Direct.	−66 18	S.E. ½ E.	−15	−2·0	−66 36	Very steady.
			S.	−66 20					
26.	−46 41	50 52	Direct.	−67 00	S.E. by S.	−36	−2·0	−67 41	
			S.	−67 06					
28.	−46 28	52 31	Direct.	−67 31	W.S.W.	+03	−2·0	−67 30	
			S.	−67 32					

Observations of the Magnetic Inclination. (Continued.)

Date.	Lat.	Long.	Method employed.	Observed Inclination.	Ship's head.	Corrections.		Corrected Inclination.	Remarks.
						Ship's attraction.	Index.		
1840.									
Apr. 29.	−46 28	52 24	Direct.	−67 11	s.w. by w.	−11	−2·0	−67 29	
			S.	−67 21					
30.	−46 17	52 04	Direct.	−66 20	s.s.w.	−45	−2·0	−67 10	
			S.	−66 27					
May 1.	−46 25	52 01	Direct.	−66 26	s. by e. ½ e.	−47	−2·0	−67 30	
			S.	−66 39					
			S.N.	−66 40					
			N.	−67 00					
2.	−46 57	55 34	Direct.	−67 37	s.e.	−26	−2·0	−68 12	
			S.	−67 51					
3.	−47 19	59 10	Direct.	−68 19	s.e.	−27	−2·0	−68 42	
			S.	−68 27					
			S.N.	−67 59					
			N.	−68 09					
4.	−47 40	62 25	Direct.	−69 13	s.e.	−28	−2·0	−69 37	
			S.	−69 02					
7.	−48 36	69 20	Direct.	−71 23	n.n.w.	+69	−2·0	−70 12	
			S.	−71 36					
8.	−48 36	69 07	Direct.	−69 12	s.w. by s.	−42	−2·0		
			S.	−69 25					
11.	−48 24	69 44	Direct.	−69 19	s.w. by w. ½ w.	−08	−2·0	−69 33	
			S.	−69 28					
12.	−48 40	68 58	Direct.	−71 47	n.	−72	−2·0	−71 35	
			S.	−72 03					
			Direct.	−69 46	s.w. by w. ½ w.	−08	−2·0		
			S.	−69 59					

Abstract of Observations of the Magnetic Force between the Cape of Good Hope and Kerguelen Island, made in Her Majesty's Ships Erebus and Terror in 1840*.

Position.		Intensity.		Position.		Intensity.	
Lat.	Long.	Cape = 0·981.	Cape = 1·000.	Lat.	Long.	Cape = 0·981.	Cape = 1·000.
−34 11	18 26	0·981	1·000†	−43 07	28 43	1·134	1·157
−37 44	16 36	0·983	1·003	−47 00	38 48	1·170	1·193
−35 14	18 27	0·984	1·004	−45 44	34 16	1·171	1·194
−36 04	19 19	0·988	1·008	−46 45	40 05	1·183	1·206
−37 16	17 24	0·989	1·009	−47 00	37 14	1·186	1·209
−36 16	20 04	0·995	1·015	−47 00	43 48	1·230	1·255
−36 52	18 25	0·996	1·016	−46 46	42 41	1·232	1·257
−36 11	20 42	0·997	1·017	−47 50	45 20	1·261	1·286
−35 48	18 47	0·998	1·018	−47 01	46 10	1·269	1·294
−38 47	17 00	0·999	1·019	−46 41	50 52	1·277	1·302
−36 35	21 20	1·010	1·030	−46 28	52 43	1·288	1·316
−38 58	17 26	1·020	1·040	−46 29	52 26	1·314	1·340
−40 05	20 38	1·021	1·041	−46 25	52 01	1·323	1·349
−40 45	19 20	1·036	1·057	−46 57	55 39	1·326	1·352
−38 13	21 30	1·045	1·066	−46 18	52 04	1·328	1·354
−42 40	22 02	1·058	1·079	−47 19	59 10	1·377	1·404
−41 24	25 00	1·063	1·084	−47 41	62 59	1·459	1·487
−42 56	23 12	1·073	1·094	−48 41	68 54	1·465	1·493
−40 29	22 22	1·079	1·100	−48 41	68 54	1·471	1·499‡
−41 58	26 38	1·088	1·110	−48 39	68 57	1·488	1·517
−44 28	24 55	1·096	1·118	−48 36	69 07	1·489	1·518
−46 41	29 00	1·122	1·144	−48 36	69 21	1·490	1·520
−46 00	26 12	1·128	1·150	−48 30	69 52	1·497	1·527
−44 19	31 06	1·131	1·154				

* Philosophical Transactions, 1842, p. 11. † On shore in Simon's Bay. ‡ On shore at Kerguelen Island.

XIX. *Meteorological Observations made on Board Her Majesty's* (*hired*) *Bark Pagoda, from January* 10 *to June* 20, 1845, *between* −20° *and* −68° *Latitude, and* 0° *and* 120° *East Longitude. By Lieut.* Henry Clerk, *Royal Artillery. Communicated by Lieut.-Colonel* Sabine, *R.A., For. Sec. R.S.,* &*c.*

Received April 21, 1846,—Read May 28, 1846.

As much interest has been taken of late in the state of the barometer in high southern latitudes, the Expedition sent last year from the Cape of Good Hope to complete the magnetical observations made by Sir James C. Ross in those latitudes, was supplied with a barometer and other meteorological instruments, and directed to make meteorological as well as magnetical observations. I have now the honour of laying before the Royal Society the observations made during that Expedition. They were taken daily at the hours of 3 and 9 a.m., 3 and 9 p.m., noon, and midnight, by the officers of the ship during their respective watches. Nothing could exceed the zeal with which the officers entered into all the objects of the Expedition, and the attention and care they took in the observations they had to make.

The following are the instruments with which the Expedition was furnished:—

One marine barometer,
Three thermometers, } by J. Newman, London.
One Daniell's hygrometer,
Ether in metal bottles.

The barometer was of the usual construction, the case being of wood and the scale of ivory, read off by a vernier to ·01 of an inch; the mercury was contained in a leathern bag. It was compared with the standard barometer at the Magnetic Observatory, Cape of Good Hope, both before and after the Expedition; and also with the Royal Society's barometer on its return to England. The following are the comparisons:—

Cape of Good Hope.—January 1845.

Standard		Marine		Marine below standard.
Barometer.	Thermometer.	Barometer.	Thermometer.	
inches.		inches.		inch.
29·863	67°·9	29·753	67°·3	·115
29·896	68·1	29·785	67·5	
29·949	69·4	29·834	69·1	
30·001	70·4	29·884	70·4	
30·067	69·0	29·948	68·5	
30·090	69·4	29·975	68·8	

Cape of Good Hope.—June 1845.

Standard		Marine		Marine below standard.
Barometer.	Thermometer.	Barometer.	Thermometer.	
inches.	°	inches.	°	inch.
30·302	55·7	30·125	55·7	·168
30·195	58·9	30·000	58·6	
30·096	59·3	29·933	59·1	
30·515	52·4	30·370	52·7	
30·097	54·2	29·935	54·3	
30·394	53·8	30·225	53·9	

At the Royal Society's Rooms, London.—March 1846.

Standard		Marine		Marine below standard.
Barometer.	Thermometer.	Barometer.	Thermometer.	
inches.	°	inches.		inch.
29·548	42·5	29·390	42·5	·149
29·430		29·280		
29·588		29·450		

From these comparisons it would appear that a change of ·05 may have taken place in the barometer during the Expedition: as the time is not known when the change took place, the mean of the three comparisons, viz. +·144 has been applied to all the observations. They have also been corrected for the effect of temperature on the mercurial column, the corrections being taken from the Table given in the Royal Society's Instructions for Magnetical and Meteorological Observatories, p. 82. The daily means thus corrected are given in the Abstract in Table I.

Table II. contains the means of every seven successive days; these means have had an additional correction applied to them, for the variation in the length of the column of mercury occasioned by the variation of gravity in different latitudes.

inch.
The correction in lat. —20° amounts to —0·059
The correction in lat. —45 amounts to —0·000
The correction in lat. —70 amounts to +0·059

and proportionally for intermediate latitudes.

Table III. contains the general results arranged according to latitude. This has been done by grouping together, without reference to date, the weekly means belonging to nearly similar latitudes. The number of observations, of which each general result is the mean, is given in the last column of the Table.

In order to resolve the heights of the barometer into the two constituents of aqueous and gaseous pressure, one of Daniell's hygrometers was observed at the hours of 9 A.M. and 3 P.M., by Assistant-Surgeon W. Dixon, M.D., attached to the Expedition. The tension of vapour obtained by these observations is taken from the Table in the Royal Society's Instructions (page 89). This being deducted from the height of the barometer in Tables II. and III., leaves the pressure of the dry air.

The thermometers, employed for observing the temperature of the air and of the surface of the sea, were frequently tested by immersing them in melting snow, and the necessary corrections have been applied. The thermometers were found to have very little index error. The temperature of the surface of the sea was obtained by drawing up water in a small canvas bucket and immersing a thermometer immediately into it.

The directions of the wind are the true ones, *i. e.* the observed compass direction corrected for the declination. The force of the wind and the state of weather were recorded according to the system drawn up by Captain BEAUFORT for the use of the Royal Navy:—frequent attempts were made to observe the force of the wind by means of one of LIND's gauges, but owing to the rolling motion of the ship it was found impossible.

The observations in the Pagoda show a lower barometer within the Tropics than a little beyond them; the mercury rising from latitude −20° to about −35°, where it stood at 30·15.

From latitude −35° to −56° the barometer fell rapidly, the difference being 1·054 inch. The descent of the mercury with the increase of latitude did not appear to extend beyond −56°, as in the forty days during which the Pagoda was between −60° and −67°·5, the mean height of the barometer scarcely differed from the mean corresponding to −56° 21′.

The gaseous pressure presents similar features, rising from −20° to −35°, thence descending to −56°, and remaining nearly constant from −56° to −67°. The difference between lat. −35° and lat. −56° amounts in this case to 0·78 inch.

No influence of longitude on the barometer is deducible from these observations, extending from 0° to 120° East.

For the purpose of comparing these results with the inferences which have been derived from previous observations, I have added an abstract of the conclusions drawn from the observations discussed in Dr. ADOLPH ERMAN's work[*], which has been communicated to me by Lieut.-Colonel SABINE.

"From a parallel very near the equator, the pressure of the atmosphere, measured by the barometer corrected for gravity, increases both northward and southward to a little beyond the outer limit of the trade winds; beyond this limit the pressure decreases, at first slowly, but much more rapidly after passing the 50th parallel. The maximum of pressure occurs at about 35° in each hemisphere. The decrease from the maximum in the direction of the Pole has been found in the southern hemisphere to continue as far as the parallel of Cape Horn (−55°·5), where the low pressure corresponds with that observed in the northern hemisphere at Kamtchatka and Sitka, which are nearly in the same latitude.

"The dry air has also a minimum zone within the inner limits of the trades; the increase from thence in both directions is more rapid and considerable than that of the pressure of the gaseous and aqueous atmospheres united, and the gaseous maximum in both hemispheres is obtained in a higher latitude (about 45°). The pressure of the dry air at its maximum at 45° exceeds the equatorial gaseous pressure by about 0·47 inch; the pressure of the whole atmosphere at its maximum in 35° is not more than 0·18 above the equatorial pressure.

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[*] Ueber Meteorologische Beobachtungen bei einer Seereise um die Erde.

"The following Table contains the approximate mean annual pressures of the atmosphere corresponding to different latitudes, as given by Dr. Erman:—1. Of the barometer; 2, of the vapour; and 3, of the dry air. The Table is formed from observations in both hemispheres, and in both the Pacific and Atlantic Oceans; it also unites observations made in different seasons, with a single exception.

Latitude.	Barometer.	Tension of the vapour.	Pressure of the dry air.	Remarks.
°	inches.	in.	in.	
0	29·98	0·77	29·21	
5	30·00	0·77	29·23	
10	30·03	0·75	29·28	
15	30·07	0·70	29·37	
20	30·11	0·65	29·46	
25	30·14	0·61	29·53	
30	30·15	0·55	29·60	
35	30·16	0·50	29·66	
40	30·12	0·44	29·68	
45	30·03	0·35	29·68	
50	29·90	0·26	29·64	Winter only.
55	29·64	0·22	29·42	

"The summer pressures of the dry air are less than the winter ones, except at the equator; the contrary is the case with the vapour."

On comparing Dr. Erman's conclusions with those drawn from the observations in the Pagoda, it appears that they agree in placing the maximum barometric pressure in lat. 35°, the pressure diminishing thence rapidly to 56°, where the Pagoda's observations show it to become nearly stationary; but they differ as to the place of the maximum pressure of the dry air, that being in lat. 40° or 45° by Dr. Erman's observations, and in lat. 35° by those of the Pagoda. It is possible however that a longer series of observations would have made the present ones agree more closely in this respect also with those of Dr. Erman, his means being taken from observations made in different seasons, and in various longitudes in both hemispheres. Taking from Dr. Erman's table 29·21 as the mean pressure of the dry air at the equator, the observations in the Pagoda show a difference of *gaseous* pressure between the equator and the high latitudes (—56° to— 67°·5) of the southern hemisphere amounting to 0·28 inch; the observations in the Pagoda were however exclusively in the summer months, when the pressures are generally less than on the mean of the whole year. Owing to the increase in the elastic force of the aqueous vapour in the warmer regions of the globe, the difference of *barometric* pressure between the equator and the high latitudes (taking the data from Dr. Erman's table on the one hand, and from the observations in the Pagoda on the other) amounts to 0·89 inch.

As the facts shown by these observations are curious, and must be interesting to meteorologists, it is hoped that the Royal Society will not consider this paper unworthy of their acceptance.

Table I.—Daily Abstract of Meteorological Observations made on board Her Majesty's (hired) Bark "Pagoda," from the 10th of January to the 20th of June 1845, between −20° and −68° latitude and 0° and 120° east longitude.

Date.	Position.		Corrected barom.	Temperature.		Hygrometer.		Wind.		Remarks.
	Lat.	Long.		Air.	Sea.	Dew-point.	Elasticity of vapour.	Direction.	Force.	
1845.	° ′	° ′	inch.	°	°	°	inch.			
Jan. 10.	−34 46	17 46	30·216	65	66	59	·497	s. by e.	4	Passing clouds.
11.	−35 29	15 09	30·154	66	66	57	·462	s. by w.	2	Passing clouds.
12.	−35 17	14 00	30·173	65	67	62	·556	s. by w.	2	Passing clouds.
13.	−35 18	13 25	30·153	66	67	61	·527	w. by n.	2	Cloudy.
14.	−37 29	13 24	30·104	60	62	51	·381	s.w. by w.	4	Cloudy and misty.
15.	−38 37	14 29	30·240	56	57	50	·359	s.w. by s.	3	Overcast and squally; strong breezes.
16.	−39 07	14 40	30·203	59	60	52	·392	w. by n.	1	Passing clouds.
17.	−40 34	14 23	29·967	60	60	54	·424	w. by s.	4	Passing clouds and misty.
18.	−43 00	13 00	29·693	56	57	47	·336	w. by n.	7	Overcast; threatening and squally.
19.	−44 58	13 19	29·714	43	44	36	·220	w.	7	Overcast and squally; passing showers.
20.	−46 34	13 33	29·362	41	42	35	·208	w.n.w.	7	Overcast; squally; heavy rain.
21.	−47 45	12 25	29·728	39	40	31	·178	e.s.e.	3	Overcast; squally; passing snow.
22.	−48 45	10 47	29·381	40	41	38	·236	n.n.w.	4	Overcast; squally.
23.	−50 40	10 23	29·299	39	39	37	·227	w.	3	Overcast and misty; drizzling rain.
24.	−51 47	9 34	29·258	38	37	36	·214	w.n.w.	1	Cloudy and snow.
25.	−53 06	7 49	29·309	36	35	29	·163	w.s.w.	4	Overcast; squally and snow; icebergs and stream-ice.
26.	−53 55	6 06	29·590	35	35	28	·159	s.s.e.	3	Cloudy; numerous icebergs.
27.	−53 13	5 57	29·743	34	34	29	·163	s.w. by w.	4	Cloudy; numerous icebergs.
28.	−57 33	4 08	29·164	33	34	Not observed.		n.n.w.	8	Overcast; squally and snow.
29.	−59 02	4 19	28·928	33	32	28	·159	Westerly.	8	Cloudy; passing snow; numerous icebergs.
30.	−60 43	4 00	28·770	32	32	29	·162	w.s.w.	6	Overcast and squally; pack ice southward to south-west.
31.	−61 10	9 07	28·769	34	33	31	·182	s.-westerly.	5	Overcast and snow; misty.
Feb. 1.	−62 02	12 49	28·575	34	33	33	·193	Southerly.	7	Cloudy; squally and passing snow.
2.	−61 54	16 27	28·953	34	34	34	·199	Southerly.	6	Cloudy and squally; no ice in sight.
3.	−61 50	19 14	29·281	34	34	32	·186	Southerly.	2	Passing clouds.
4.	−62 00	20 36	29·231	33	34	31	·177	n.e. by e.	3	Overcast; passing snow.
5.	−63 19	21 15	29·294	32	33	31	·181	e. by n.	1	Overcast; broken ice in streams.
6.	−64 25	24 10	29·375	33	33	30	·172	n.e. by n.	3	Passing clouds; very clear.
7.	−65 39	28 40	29·583	33	33	29	·162	n. by e.	4	Passing clouds; very clear.
8.	−66 25	30 45	29·711	29	30	25	·144	s.s.e.	2	Passing clouds; misty.
9.	−66 36	36 50	29·271	28	29	25	·141	n.w. by w.	4	Passing clouds.
10.	−67 03	38 51	29·271	31	31	24	·136	e. by n.	2	Cloudy; no ice in sight.
11.	−67 38	39 41	29·173	30	30	24	·139	Easterly.	1	Passing clouds and snow; pack ice in sight.
12.	−66 40	39 24	29·221	29	30	23	·134	e. by s.	2	Overcast; passing snow.
13.	−67 25	40 14	28·912	31	31	23	·133	n.e. by e.	6	Cloudy and snow squalls.
14.	−66 25	40 01	28·694	32	32	28	·159	e. by n.	9	Cloudy and snow squalls; strong gale.
15.	−65 38	38 52	28·682	32	32	29	·163	e. by n.	10	Cloudy and snow squalls; strong gale.
16.	−64 52	38 37	28·761	34	33	30	·172	e. by n.	4	Cloudy and fog.
17.	−64 52	40 12	28·937	34	34	30	·172	n. ½ e.	2	Cloudy; snow.
18.	−64 22	40 29	28·674	33	33	27	·153	n.e. ½ e.	9 to 11	Overcast; heavy gale; incessant snow.
19.	−64 00	41 00	28·606	33	34	29	·168	n.w. by n.	4	Overcast.
20.	−63 19	45 45	29·104	33	33	28	·159	n. by w. ½ w.	5	Passing clouds and misty.
21.	−63 36	46 48	28·814	33	33	26	·146	n. by e.	0	Passing clouds and snow.
22.	−63 43	49 29	28·707	32	32	29	·163	n.e. by n.	6	Overcast; snow squalls.
23.	−63 42	50 19	28·550	32	32	Not observed.		n.e. by n.	6	Overcast; snow squalls.
24.	−62 36	51 15	28·519	32	32	29	·163	s.s.e.	6	Overcast; snow and sleet.
25.	−61 30	53 43	29·069	32	31	23	·134	s.s.e.	3	Passing clouds; very clear.
26.	−61 19	57 33	29·390	33	33	29	·165	Westerly.	4	Passing clouds and snow; very clear.
27.	−61 48	64 14	29·538	33	32	29	·163	Southerly.	6	Passing clouds; very clear.
28.	−61 43	71 13	29·598	34	32	31	·182	s.s.w.	4	Passing clouds; aurora seen.
Mar. 1.	−62 10	72 25	29·590	36	33	31	·179	s.-westerly.	1	Overcast; very clear.
2.	−62 44	76 11	29·501	36	33	26	·146	n.-easterly.	3	Cloudy; very clear.
3.	−64 15	79 44	29·007	31	32	28	·159	e. by n.	5	Overcast.
4.	−63 02	80 27	28·535	33	32	Not observed.		s.e.	7	Overcast; passing snow.
5.	−61 41	84 57	28·714	32	31	28	·160	s.s.w.	5	Passing clouds; brilliant aurora.
6.	−60 48	88 23	28·821	33	32	26	·146	w.s.w.	4	Cloudy; snow and fog.
7.	−61 23	91 13	28·755	34	33	28	·159	n.n.e.	3	Passing clouds; very brilliant aurora.
8.	−61 10	92 07	28·720	34	33	29	·165	s.-easterly.	3	Blue sky; very clear; numerous icebergs.
9.	−60 32	92 27	28·849	36	34	27	·156	s.-easterly.	3	Cloudy and snow; aurora visible.
10.	−60 03	95 36	29·048	33	32	24	·135	Southerly.	4	Cloudy; aurora seen.
11.	−59 49	99 45	29·024	32	32	28	·159	Variable.	4	Cloudy; passing snow.
12.	−58 31	98 59	28·512	33	32	28	·159	e.n.e.	7	Overcast; snow squalls.
13.	−57 53	99 08	28·729	35	33	26	·145	s. by w.	6	Overcast; snow squalls.
14.	−56 50	101 28	29·184	36	34	32	·186	w. ½ n.	5	Passing clouds; occasional snow.
15.	−55 45	103 12	29·059	36	34	33	·196	w. ½ n.	5	Overcast and snow squalls; aurora.
16.	−54 42	106 08	28·877	36	35	34	·200	w. ½ s.	6	Overcast; heavy squalls of snow.

TABLE I. (Continued.)

Date.	Position.		Corrected barom.	Temperature.		Hygrometer.		Wind.		Remarks.
	Lat.	Long.		Air.	Sea.	Dew-point.	Elasticity of vapour.	Direction.	Force.	
1845.	° ′	° ′	inch.	°	°	°	inch.			
March 17.	−54 15	108 09	28·627	37	37	Not observed.		N.N.W.	6	Cloudy; passing snow squalls.
18.	−53 08	110 29	28·867	39	37	35	·212	S.W. by W.	4	Passing clouds; aurora seen faintly.
19.	−51 10	111 23	29·357	40	38	36	·220	W. ½ S.	7	Cloudy; passing squalls; aurora seen faintly.
20.	−49 01	112 51	30·049	44	42	39	·242	W. ½ N.	4	Cloudy; aurora seen.
21.	−48 06	114 34	29·882	48	47	Not observed.		N.W. by N.	6	Overcast; misty; heavy rain squalls.
22.	−47 21	115 15	29·671	47	46	42	·270	N. by W. ½ W.	2	Overcast; misty and fog.
23.	−47 03	115 58	29·394	45	44	38	·237	W. by S.	9	Overcast; passing showers; squally.
24.	−45 12	116 47	29·686	51	49	45	·302	W. by N.	7	Overcast and squally.
25.	−43 28	116 52	29·996	51	49	44	·296	W.	3	Passing clouds; very clear.
26.	−41 08	116 42	30·001	53	52	45	·302	W. ¾ S.	5	Passing clouds.
27.	−38 42	116 15	30·213	54	52	47	·330	S.W. by S.	3	Passing clouds; very clear.
28.	−37 03	116 57	30·314	58	58	56	·447	W.S.W.	1	Overcast; wind variable.
29.	−36 11	116 50	30·272	61	63	59	·497	Variable.	1	Overcast; heavy rain.
30.	−35 14	117 37	30·121	66	65	56	·449	E. by N.	4	Passing clouds; very clear.
31.	−35 28	117 04	30·130	64	63	57	·455	E. by S.	3	Passing clouds.
April 1.	−35 03	117 56	30·140	65	65	58	·471	E.S.E.	4	Passing clouds; very clear.
2.	At anchor in Princess Royal Harbour.	King George's Sound, West Australia.	30·184	64	65	58	·471	S.E. ½ E.	3	Overcast; passing showers.
3.			30 181	65	64	52	·389	E.N.E.	2	Passing clouds.
4.			30·149	66	64	57	·455	N.E. ½ E.	3	Passing clouds.
5.			30·073	69	64	58	·480	E. by S.	2	Passing clouds.
6.			29·920	71	66	59	·497	N.W. ½ W.	2	Blue sky and detached clouds.
7.			29·998	63	64	52	·396	W.S.W.	4	Passing clouds and squally.
8.			30·191	63	62	57	·463	W.S.W.	4	Passing clouds.
9.			30·295	64	65	54	·424	E. by S.	2	Passing clouds; very clear.
10.			30·255	65	64	49	·356	N.E.	2	Passing clouds.
11.			30·146	70	64	47	·324	E. by N.	3	Passing clouds; very clear.
12.			29·961	67	64	61	·535	S.W. by W.	2	Passing clouds.
13.			30·056	65	64	55	·443	N.W.	2	Passing clouds.
14.			30·161	68	65	58	·488	S.S.E.	1	Passing clouds; fine weather.
15.			30·001	67	66	57	·472	W. ½ S.	2	Passing clouds.
16.			29·818	64	64	60	·514	W.N.W.	5	Cloudy; strong breezes and squally.
17.			29·879	62	61	Not observed.		W.S.W.	6	Cloudy; squally and heavy rain.
18.			30·159	58	61	49	·348	S.W.	5	Cloudy and squally.
19.			30·330	57	60	54	·429	W.S.W.	3	Passing clouds and squalls.
20.			30·322	63	61	57	·471	S.E. ½ E.	0	Passing clouds.
21.			30·166	67	66	55	·440	E.N.E.	3	Passing clouds.
22.	−35 42	115 55	29·980	70	65	63	·570	N.-westerly.	0	Light, variable airs, and fine.
23.	−35 34	114 39	29·997	62	63	50	·362	W.N.W.	3	Cloudy and rain; variable wind.
24.	−34 12	113 05	30·229	63	63	50	·370	S.S.W.	3	Passing clouds and showers.
25.	−32 28	111 32	30·307	65	64	54	·417	E.S.E.	3	Passing clouds; wind variable.
26.	−30 26	109 06	30·130	69	65	64	·600	Easterly.	5	Passing clouds.
27.	−29 16	106 49	29·985	70	68	63	·580	Northerly.	5	Passing clouds; wind variable.
28.	−27 41	106 34	29·945	69	67	59	·506	W.N.W.	5	Overcast; passing squalls.
29.	−25 52	105 02	30·068	68	67	58	·480	S.S.W.	6	Passing clouds; strong breezes and squally.
30.	−24 04	102 24	30·150	68	68	57	·463	Southerly.	5	Cloudy and squally; wind variable.
May 1.	−23 58	99 13	30·178	68	70	55	·440	S. ½ E.	2	Cloudy; occasional squalls and rain.
2.	−24 01	92 27	30·057	69	68	58	·480	Easterly.	1	Overcast; drizzling rain; wind variable.
3.	−23 55	95 58	29·997	72	69	63	·580	N.E.	3	Passing clouds.
4.	−24 17	93 55	29·905	74	71	68	·676	Northerly.	3	Cloudy; passing squalls and rain; wind variable.
5.	−24 28	92 07	29·897	73	71	69	·698	Westerly.	5	Overcast; strong breezes and squally.
6.	−22 45	90 38	30·028	72	69	56	·448	S.S.W.	2	Overcast; very clear.
7.	−21 46	89 40	30·100	73	71	58	·488	S.S.E.	2	Passing clouds; very clear.
8.	−20 38	87 56	30·132	75	72	63	·580	E. by S.	4	Passing clouds; light breezes, and fine.
9.	−20 37	85 19	30·116	74	73	65	·622	E. by S.	4	Cloudy; occasional rain.
10.	−20 25	82 10	30·095	74	74	66	·632	E.S.E.	5	Overcast and squally.
11.	−20 36	79 13	30·051	76	73	64	·590	E.S.E.	3	Passing clouds; fresh breezes, and fine.
12.	−20 44	78 31	29·997	77	72	62	·560	S.-easterly.	2	Passing clouds; very clear.
13.	−20 39	77 43	29·940	76	74	65	·622	S.S.E.	1	Passing clouds; light airs, and fine.
14.	−20 28	76 13	29·932	75	73	67	·655	E.S.E.	4	Overcast; very clear; strong breezes.
15.	−20 34	73 17	29·904	75	72	72	·773	Easterly.	6	Overcast; heavy rain.
16.	−20 27	70 39	29·832	75	74	74	·825	Easterly.	3	Cloudy; heavy rain and lightning.
17.	−20 54	69 25	29·762	78	77	73	·801	Variable.	1	Overcast; heavy rain.
18.	−21 08	68 08	29·812	77	76	68	·676	W.N.W.	2	Cloudy; light variable airs.
19.	−21 11	67 54	29·885	76	74	67	·664	W.S.W.	2	Passing clouds.
20.	−21 12	67 29	29·967	75	74	66	·643	S.W. by S.	1	Passing clouds.
21.	−21 01	65 56	30·011	75	73	63	·570	Southerly.	3	Passing clouds; very clear.
22.	−20 41	63 00	30·104	75	72	58	·489	S. by E. ½ E.	3	Passing clouds.
23.	−20 30	59 32	30·184	75	73	61	·535	S.S.E.	6	Cloudy; squally, with rain.
24.	−20 09	57 31	30·204	75	74	66	·632	E. by S.	5	Overcast; squally and misty.

Table I. (Continued).

Date.	Position.		Corrected barom.	Temperature.		Hygrometer.		Wind.		Remarks.
	Lat.	Long.		Air.	Sea.	Dew-point.	Elasticity of vapour.	Direction.	Force.	
1845.	° ′	° ′	inch.	°	°	°	inch.			
May 25.	At anchor, Port Louis, Mauritius.		30·204	74	73	63	·570	E. by S.	4	Passing clouds and squalls.
26.			30·190	77	72	63	·570	S.E. by E.	3	Passing clouds.
27.			30·169	76	72	59	·505	S.E. by E.	3	Cloudy; squally and rain.
28.			30·165	77	74	64	·591	S.E. by E.	3	Passing clouds.
29.	−20 50	55 32	30·160	78	74	62	·561	Easterly.	3	Passing clouds and haze.
30.	−21 50	53 30	30·144	77	74	64	·590	N.-easterly.	5	Passing clouds.
31.	−23 32	51 59	30·107	78	76	67	·665	Easterly.	3	Passing clouds; moderate breezes and fine.
June 1.	−25 59	49 28	29·949	75	74	70	·723	Northerly.	7	Cloudy; heavy squalls and rain.
2.	−26 25	49 11	29·974	73	72	60	·516	S.-westerly.	6	Cloudy; strong breezes and squalls.
3.	−26 23	48 25	30·076	70	70	54	·424	S. by E.	6	Passing clouds; heavy squalls.
4.	−27 14	45 59	30·260	68	70	54	·417	S.-easterly.	4	Passing clouds; very clear.
5.	−28 26	42 48	30·087	69	71	64	·590	Easterly.	5	Overcast; heavy squalls and rain.
6.	−28 46	41 56	30·000	68	70	58	·488	W.S.W.	5	Overcast and squally.
7.	−28 38	40 18	30·201	70	69	58	·488	S.	6	Passing clouds; strong breezes.
8.	−28 58	37 49	30·298	72	70	54	·424	Easterly.	3	Passing clouds; wind variable.
9.	−30 23	35 24	29·986	71	71	66	·632	Northerly.	6	Squally; with heavy rain and lightning.
10.	−31 03	33 56	29·892	68	70	58	·480	W.	8	Cloudy; heavy squalls and rain.
11.	−30 27	33 41	30·093	66	68	54	·417	S.S.W.	3	Cloudy and rain.
12.	−30 35	33 13	30·215	65	67	51	·384	Southerly.	3	Passing clouds and rain.
13.	−31 10	31 28	30·490	65	67	47	·324	S.S.E.	3	Cloudy and squally, with lightning.
14.	−33 03	29 23	30·472	68	69	57	·463	Northerly.	3	Passing clouds.
15.	−34 51	26 46	30·351	71	70	56	·447	Northerly.	3	Passing clouds; hazy.
16.	−35 45	23 28	30·128	70	69	55	·432	N.N.W.	2	Passing clouds; very clear.
17.	−35 40	21 30	30·026	63	66	58	·480	Northerly.	2	Cloudy; light variable airs.
18.	−35 05	20 44	30·149	60	58	56	·455	W.N.W.	1	Passing clouds; in soundings.
19.	−35 08	20 24	30·275	58	58	53	·403	S.W. by W.	1	Overcast.
20.	−34 55	19 27	30·406	58	58	50	·368	S.E.	1	Passing clouds; very clear.

Table II.

Date.	Lat.	Barometer corrected.	Tension of vapour.	Gaseous pressure.	Temperature of air.
1845.	° ′	inches.		inches.	°
January 10 to 16.	−36 35	30·148	·453	29·695	62
17 to 23.	−46 02	29·593	·261	29·332	45
24 to 30.	−55 37	29·280	·170	29·110	34
January 31 to February 6.	−62 40	29·111	·184	28·927	33
February 7 to 13.	−66 47	29·354	·141	29·213	30
14 to 20.	−64 47	28·828	·164	28·664	33
21 to 27.	−62 36	28·985	·156	28·829	32
February 28 to March 6.	−62 20	29·153	·162	28·991	34
March 7 to 13.	−59 54	28·843	·154	28·689	34
14 to 20.	−53 33	29·168	·209	28·959	38
21 to 27.	−44 23	29·834	·289	29·545	50
March 28 to April 3.	−35 41	30·169	·454	29·715	63
April 4 to 10.	−35 03	30·103	·439	29·664	66
11 to 17.	−35 03	29·980	·463	29·517	66
18 to 24.	−35 06	30·136	·427	29·709	63
April 25 to May 1.	−27 41	30·066	·498	29·568	68
May 2 to 8.	−23 07	29·971	·564	29·407	73
9 to 15.	−20 35	29·947	·636	29·311	75
16 to 22.	−20 53	29·852	·667	29·185	76
23 to 29.	−20 18	30·124	·566	29·558	76
May 30 to June 5.	−25 41	30·037	·561	29·476	73
June 6 to 12.	−29 50	30·060	·473	29·587	69
13 to 19.	−34 23	30·242	·429	29·813	65
20.	−34 55	30·378	·368	30·010	58

Table III.

Lat.	Corrected barometer.	Tension of vapour.	Gaseous pressure.	Temperature of air.	Number of observations.
° ′	inches.		inches.	°	
−20 35	29·981	·623	29·358	76	126
−24 24	30·004	·562	29·442	73	84
−28 45	30·063	·486	29·577	68	84
−35 15	30·151	·433	29·718	63	258
−45 12	29·710	·275	29·435	47	84
−56 21	29·097	·178	28·919	35	126
−62 32	29 083	·167	28·916	33	126
−65 47	29·091	·153	28·938	31	84

PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXLVI.

PART IV.

LONDON:

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MDCCCXLVI.

ADJUDICATION of the MEDALS of the ROYAL SOCIETY for the year 1846 by the PRESIDENT and COUNCIL.

The COPLEY MEDAL to U. J. LE VERRIER, for his investigations relative to the disturbances of Uranus, by which he proved the existence and predicted the place of the new Planet.

The RUMFORD MEDAL to MICHAEL FARADAY, ESQ., LL.D., F.R.S., for his discovery of the Optical Phenomena developed by the action of Magnets and Electric Currents in certain Transparent Media, published in the Philosophical Transactions for 1846.

The ROYAL MEDAL in the department of Physics, to MICHAEL FARADAY, ESQ., LL.D., F.R.S., for his Experimental Researches in Electricity. Twentieth and Twenty-first Series.—On new Magnetic Actions, and on the Magnetic Conditions of all Matter, published in the Philosophical Transactions for 1846.

No recommendation of the ROYAL MEDAL in the department of Geology having been received, it was awarded to RICHARD OWEN, ESQ., F.R.S., for his paper entitled "A Description of certain Belemnites, preserved, with a great proportion of their soft parts, in the Oxford Clay," published in the Philosophical Transactions for 1844.

The paper appointed for the BAKERIAN LECTURE for the year 1846, is Professor FORBES'S "Illustrations of the Viscous Theory of Glacier Motion."

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Presents . . . . [1]

ERRATA.

Philosophical Transactions, Part II. for 1845, in Dr. Davy's Paper on the Temperature of Man,

Page 320, line 25, *erase* shall.

Page 322, line 9, *for* feeling. The effect and perhaps best sign of the happy temperate mean in some facts, *read* feeling,—the effect and perhaps best sign of the happy temperate mean. Some, &c.

PHILOSOPHICAL TRANSACTIONS.

XX. *On the Barometrical Variation as affected by the Moon's Declination.*

By Luke Howard, *Esq., F.R.S.*

Received January 16,—Read June 19, 1845.

THESE calculations were begun with the year 1815, and continued to 1832: the present paper continues them to 1841. The method used to bring out the averages may be thus described. Beginning as nearly as may be at the winter solstice, the days of a solar year are classed in what may be termed *weeks of declination*, mostly of seven days each, the middle day of each week corresponding,—1, with the moon's position coming north from the equator; 2, with her position in full north declination; 3, with her position returning to south over the equator; 4, with her full south declination. The average, or mean height of the barometer, in each of these classes, is presumed to express the relative power, or effect, of the position to which it belongs; when divested of the much larger amount of variation due to the effect of a northerly or southerly current, of the variable pressure of the aqueous atmosphere, of the temperature of the season, the deposition of rain, &c. Mixed with *these*, the weekly averages offer a mass of results sufficiently discordant; but the discrepancy vanishes when those under each class are *averaged upon the solar year*; the other movements now balancing and neutralising each other.

The present series of averages extends then from December 20, 1832, where the former ends, to December 23, 1841. It corresponds nearly with the latter or *cold* half of the cycle of annual temperatures, which I have already laid before the public. And it being probable that a close connexion exists between the pressure and the temperature of the atmosphere of these latitudes, in its variations, my taking these limits may facilitate to students a careful comparison of the two, throughout a cycle.

In my paper of March 1841, the mean height of the barometer for each of the four positions came out, by averages upon eighteen years ending with 1832, as follows, viz.—

Moon coming north over equator	29·8724 in.
Moon in north declination	29·8608 in.
Moon going over equator, south	29·8450 in.
Moon in south declination	29·8261 in.

Hence it was inferred that the barometrical mean is *depressed* in these latitudes by the moon's position in south declination: and that which appeared upon the aggregate of years, was found to hold also in the several nine-years' averages of which it consisted. The depression was stated to be gradual, proceeding through the three changes to the south place; but upon the planet's quitting her south position to return north, a sudden elevation of the mean, effected in a single week of declination, indicated the return of the pressure (as far as regarded *this* influence) to its former limit.

The results of the present examination differ somewhat in the proportions of pressure shown; the chief cause being, as I apprehend, the different latitude in which a part of the observations took place. In 1828, near the middle of the year, having given up my house on Tottenham-green, I removed the barometer-clock to the Villa, Ackworth, Yorkshire, in latitude 53° 39′ north, and still on the east side of the island. Here I obtained for some time the yearly circle of the variation: but coming subsequently to spend the winter in the south, from my absence joined with other causes, the clock for several months in the year stood still. I had presented a good barometer to the Friends' Institution at Ackworth, where a good meteorological register is kept at my instance; and from *this* the maxima and minima, wanting in the series by the clock, have been taken.

Thus circumstanced, and the instrument standing, from the above date, on considerably higher ground, and 2° more to the north, the averages from 1824 to 1832 come out as follows, viz. moon coming north 29·8505 in.; in north declination 29·8257 in.; going south 29·8076 in.; in south declination 29·8058 in. Here we have still the depression to the place of south declination; but with a check, amounting almost to the doing of it away, in the concluding position. Let us, however, see further.

On the solar years, from 1833 to 1841, *observed wholly at Ackworth*, the averages are,—

Moon coming north	29·7127 in.
Moon in north declination . . .	29·6946 in.
Moon going south	29·6969 in.
Moon in south declination . . .	29·7115 in.

The former variation, presenting a gradual decline of gravity to the moon's south place, is here replaced by one altogether different; the loss of gravity by the north declination continues into the following week, and is restored (very nearly) in the fourth week; the moon yet full *south*. Had this discrepancy resulted from less perfect observation merely, it ought to have affected each position alike, and to have made the calculations useless; but we have here even more of *symmetry* than before. There must be something then in the more northern latitude, affecting partially the *mixed* average 1824 to 1832, and more completely the *northern* average 1833 to 1841; which is commended, with all deference, to the study and consideration of our mathematical and astronomical Fellows.

In my former paper, I exhibited likewise a set of averages *upon the whole solar year*, from 1815 to 1832, in which the *yearly mean pressure* increases to the middle of a cycle of eighteen years, and then decreases with great regularity to its former amount. I have inserted here a similar calculation, but with an opposite result; which shows the pressure decreasing from year to year, and then recovering in some measure its former level: but this, for reasons already given, comes out less regular and symmetrical than the other. I have no doubt that, when we shall have prosecuted further the comparison of the yearly mean pressures with the temperatures, there will be found a contrast between the two halves of a cycle as evident as that I have shown to exist in those of the cycle of temperature.

In the long average, 1815 to 1841, we have,—1, a half cycle *cold*; 2, a half cycle *warm*; 3, a half cycle *cold*; the result of which must needs show a preponderance of the effect of cold. But let the temperatures balance, as in the cycle 1815–32, we have then—1, coming north 29·8310 in.; 2, north 29·8260 in.; 3, going south 29·8171 in.; 4, south 29·8056 in. Again, in the balanced cycle 1824–41, we have for the four respectively,—1, coming north 29·7816 in.; 2, north 29·7601 in.; 3, going south 29·7522 in.; 4, south 29·7586 in. The results of this last average are subject in some degree to the effect of a more northerly site. Without presuming to determine even that latitude has such an effect in a space of less than three degrees, I have thought it right to place these data in the hands of the Fellows, that future students may have the opportunity (now that we have begun to distinguish between the various causes affecting the gravity of the atmosphere) of comparing (with much trouble saved) the actual differences which obtain in it, under different positions of the planet; and of analysing, with the help of the register whence they are derived, a great mass of observations tending to throw light on the nascent science of meteorology.

I have to acknowledge, in concluding this paper, my obligations to my young friend Cornelius Hanbury, who made for me the preliminary calculations upon the register with much care, and, I am satisfied, with the required accuracy.

L. H.

Ackworth, October 25, 1844.

Barometrical Averages, &c.

Year.	Days.	Coming North.	North.	Going South.	South.	On the year.
		in.	in.	in.	in.	in.
1833.	369	29·5807	29·6497	29·5333	29·5812	29·5862
1834.	362	29·7733	29·6997	29·6653	29·6001	29·6846
1835.	368	29·8053	29·8507	29·8631	29·8659	29·8462
1836.	362	29·7749	29·4987	29·6004	29·6010	29·6187
1837.	369	29·7098	29·7588	29·6514	29·6595	29·6949
1838.	362	29·5696	29·7061	29·7283	29·6866	29·6702
1839.	368	29·7672	29·7347	29·7626	29·8158	29·7703
1840.	362	29·7851	29·7474	29·7724	29·8699	29·7932
1841.	369	29·6488	29·6055	29·6957	29·7139	29·6659
On nine solar years, 1833–1841.		29·7127	29·6946	29·6969	29·7115	29·7034

Years.	Coming North.	North.	Going South.	South.	On nine years.
	in.	in.	in.	in.	in.
1825–1833.	29·8063	29·7965	29·7812	29·7874	29·7928
1826–1834.	29·7719	29·7599	29·7448	29·7440	29·7552
1827–1835.	29·7403	29·7410	29·7306	29·7301	29·7355
1828–1836.	29·7223	29·6969	29·6896	29·6877	29·6991
1829–1837.	29·7057	29·6943	29·6732	29·6653	29·6846
1830–1838.	29·6930	29·6998	29·6779	29·6638	29·6836
1831–1839.	29·6960	29·7103	29·6782	29·6778	29·6906
1832–1840.	29·7126	29·7177	29·7007	29·7081	29·7098
1833–1841.	29·7127	29·6946	29·6969	29·7115	29·7039
On twenty-seven solar years, 1825–1841.	29·7290	29·7234	29·7081	29·7084	29·7172

Years.		Coming North.	North.	Going South.	South.	
		in.	in.	in.	in.	in.
1815–1823.	On nine years, the barom. at Tottenham. .	29·8115	29·8263	29·8267	29·8054	
1824–1832.	On nine years, the barom. moved 1828.	29·8505	29·8257	29·8076	29·8058	
1833–1841.	On nine years, the barom. at Ackworth . .	29·7127	29·6946	29·6969	29·7115	
	Mean of the three	29·7916	29·7822	29·7771	29·7742	
				Mean of the whole. . . .		29·7812

Barometrical Averages, &c.

Year and Periods.	Days.	Coming N.	Days.	North.	Days.	Going S.	Days.	South.
		in.		in.		in.		in.
Dec. 20–26, 1832	....	....	....	....	....	....	7	29·5243
Dec. 27 to Jan. 22, 1833.	7	29·7886	6	30·2941	7	29·9000	7	30·1257
Jan. 23 to Feb. 18	7	29·7621	7	29·1871	6	29·2008	7	29·0021
Feb. 19 to March 18	7	29·4257	7	29·1750	7	29·9757	7	29·4300
March 19 to April 14	7	29·7528	6	29·5566	7	29·3500	7	29·3143
April 15 to May 12	7	29·5621	7	29·7578	6	29·4266	8	29·8443
May 13 to June 8	6	29·7583	7	29·9700	6	29·9425	8	29·5206
June 9 to July 5	7	29·4278	6	29·5908	7	29·4371	7	29·6064
July 6 to August 1	7	29·6471	7	29·7207	6	29·5450	7	30·0657
August 2–29	7	29·8978	7	29·5928	6	29·4733	8	29·6631
August 30 to Sept. 25	7	29·5185	6	29·7358	7	29·5121	7	29·5678
Sept. 26 to Oct. 22	7	29·7193	7	29·8985	6	29·3600	7	29·1928
Oct. 23 to Nov. 18	7	29·4064	6	29·5935	7	29·5966	7	29·8314
Nòv. 19 to Dec. 16	7	29·4021	7	29·3735	7	29·2128	7	29·4478
December 17–23	7	29·0607						
369 days.	97	29·5807	86	29·6497	85	29·5333	101	29·5812
Dec. 24, 1833 to Jan. 12, 1834	....	....	7	29·3893	6	29·6225	7	29·0400
January 13 to February 8.	7	29·2743	7	29·4314	7	29·6665	6	29·7358
February 9 to March 7	8	29·9112	6	29·7541	7	29·9107	6	29·6891
March 8 to April 4	8	30·1481	7	30·1021	6	29·5241	7	29·8421
April 5 to May 1	7	30·0693	7	30·0500	7	30·0064	6	29·3016
May 2–28	8	29·7243	6	29·5083	7	29·6950	6	30·0875
May 29 to June 25	8	29·7450	6	29·4983	7	29·4121	7	29·7314
June 26 to July 22	7	29·9200	7	29·7371	7	29·6593	6	29·4933
July 23 to August 19	8	29·6331	6	29·5483	7	29·6150	7	29·7386
August 20 to Sept. 15	7	29·4207	6	29·4258	7	29·5286	7	29·7578
Sept. 16 to Oct. 12	7	29·8907	7	29·7886	6	29·8091	7	29·6936
Oct. 13 to Nov. 8	7	29·3236	7	29·6564	7	29·8757	6	29·2058
Nov. 9 to Dec. 6	7	29·9678	8	29·7675	6	29·3233	7	29·4850
December 7–20	7	30·0243	7	30·1393				
362 days.	96	29·7733	94	29·6997	87	29·6653	85	29·6001
Dec. 21, 1834 to Jan. 2, 1835	....	....	....	....	7	30·0643	6	29·8567
January 3–29	7	29·9671	7	29·4850	7	29·7264	6	30·1666
January 30 to February 25.	7	30·0557	8	29·9831	6	29·3791	6	29·1775
February 26 to March 25.	8	29·5162	7	29·4271	7	29·9464	6	30·3758
March 26 to April 21	7	29·9807	7	30·1186	7	30·1214	6	30·2541
April 22 to May 19	8	29·9812	7	29·7278	6	29·7283	7	29·7500
May 20 to June 15	6	29·9008	8	29·9106	6	29·9558	7	30·2786
June 16 to July 12	7	29·9078	7	29·7628	7	29·9678	6	29·7733
July 13 to August 8	7	29·8571	8	30·1987	6	30·0375	6	29·9716
August 9 to September 5.	8	30·0769	7	29·8207	6	29·7808	7	30·0129
September 6 to October 2.	7	29·4550	7	29·5750	7	29·5700	6	29·1733
October 3–29	7	29·5417	7	29·8793	7	29·7829	6	29·5425
October 30 to Nov. 26	7	30·0121	8	30·1881	6	29·8450	7	29·5571
November 27 to Dec. 23.	7	29·2164	7	29·9821	7	30·1786	6	30·2325
368 days.	93	29·8053	95	29·8507	92	29·8631	88	29·8659

Barometrical Averages, &c.

Year and Periods.	Days.	Coming N.	Days.	North.	Days.	Going S.	Days.	South.
		in.		in.		in.		
Dec. 24, 1835 to Jan. 19, 1836	7	30·1350	7	30·1007	7	29·4714	6	29·9450
Jan. 20 to Feb. 16......	7	29·6457	7	29·0393	7	29·7700	7	30·0293
February 17 to March 14.	6	30·0133	7	29·0414	8	29·2000	6	28·9300
March 15 to April 10 ..	7	29·7564	7	29·0671	7	29·6335	6	29·3508
April 11 to May 8......	7	29·7843	8	29·7244	6	29·7300	7	29·9786
May 9 to June 4	6	30·1391	8	30·0775	7	30·1714	6	29·5825
June 5 to July 1	6	29·5066	8	29·6937	7	29·6243	6	29·7741
July 2–28	7	29·9357	7	29·5807	7	29·4935	6	29·6441
July 29 to August 25 ..	7	29·7300	8	30·0175	7	29·7607	6	29·6450
August 26 to Sept. 21 ..	6	29·7225	8	29·3287	7	29·8807	6	29·8816
Sept. 22 to October 18 ..	7	29·6143	7	29·1050	7	29·0200	6	29·7158
Oct. 19 to Nov. 15	7	30·0757	8	29·6481	6	29·6116	7	29·3857
Nov. 16 to Dec. 12	6	29·3076	8	29·0594	7	29·4378	6	28·9508
December 13–19	7	29·4828						
362 days.	93	29·7749	98	29·4987	90	29·6004	81	29·6010
Dec. 20, 1836 to Jan. 8, 1837	....	....	7	29·8028	7	30·0964	6	29·8558
Jan. 9 to Feb. 5	7	29·7293	8	29·8131	7	29·6328	6	30·0025
Feb. 6 to March 4......	7	29·4414	7	29·3878	7	29·4893	6	29·9933
March 5–31	7	29·6178	7	29·9378	7	29·5564	6	29·5491
April 1 to 28..........	7	29·5535	7	29·7250	7	29·4550	7	29·3750
April 29 to May 25	7	29·4535	7	29·5757	7	29·8385	6	29·5741
May 26 to June 21	7	29·6471	7	29·7700	7	29·4428	6	29·5775
June 22 to July 19	7	29·9214	7	29·8828	7	29·8285	7	29·4764
July 20 to August 15 ..	7	29·6957	6	29·2683	8	29·9118	6	30·0016
August 16 to Sept. 11 ..	7	29·6578	7	29·8621	7	29·5843	6	29·6491
Sept. 12 to October 9 ..	7	29·5714	7	30·1271	7	30·0593	7	30·0228
October 10 to Nov. 5 ..	7	30·1714	6	29·9350	7	29·1971	7	29·0793
November 6 to Dec. 2 ..	7	29·7257	7	29·5578	7	29·3657	6	29·4166
December 3–23	7	30·0418	6	29·9775	8	29·6618		
369 days.	91	29·7098	96	29·7588	100	29·6514	82	29·6595
Dec. 24–30, 1837	....	....	....	....	....	....	7	29·7128
Dec. 31 to Jan. 26, 1838..	6	29·8166	7	30·2093	8	29·9450	6	29·6275
Jan. 27 to Feb. 22......	7	29·7735	7	29·6257	7	29·5421	6	29·7900
Feb. 23 to March 22....	7	29·0107	6	29·4400	8	29·9170	7	29·3164
March 23 to April 18 ..	6	29·9400	7	30·0471	7	29·6014	7	29·7335
April 19 to May 15	7	29·5357	6	29·6825	8	30·0125	6	29·5541
May 16 to June 11	7	29·3178	6	29·5433	8	29·4331	6	29·5325
June 12 to July 9	7	29·4364	7	29·4621	7	29·5914	7	29·6164
July 10 to August 5....	7	29·4643	6	29·6758	7	29·6593	7	29·5485
August 6 to Sept. 1	7	29·7471	7	29·9114	7	29·4707	6	29·9083
September 2–29........	7	29·5743	7	30·1450	7	29·8107	7	29·8071
Sept. 30 to October 26 ..	6	30·3225	7	29·9721	7	29·4271	7	29·7535
October 27 to Nov. 22 ..	7	29·2678	6	29·1391	7	29·8557	7	29·5221
November 23 to Dec. 20 ..	7	29·1985	6	29·3266	8	30·2018	7	30·1907
362 days.	88	29·5696	85	29·7061	96	29·7283	93	29·6866

Barometrical Averages, &c.

Year and Periods.	Days.	Coming N.	Days.	North.	Days.	Going S.	Days.	South.
		in.		in.		in.		in.
Dec. 21, 1838 to Jan. 16, 1839	7	29·6593	6	30·0075	7	29·3828	7	29·8335
Jan. 17 to Feb. 12	6	29·7066	7	30·0500	7	29·7338	7	30·1707
Feb. 13 to March 12....	7	29·5764	7	29·7157	7	30·0678	7	29·9528
March 13 to April 8	6	29·6983	7	29·5778	7	29·5364	7	30·1393
April 9 to May 6	7	30·3028	6	29·6591	7	30·0828	8	29·8706
May 7 to June 2	6	30·0133	7	29·7085	6	30·0375	8	30·0875
June 3–29	6	29·7108	7	29·9914	7	29·7457	7	29·6343
June 30 to July 26	6	30·0841	7	29·5835	7	29·6671	7	29·6221
July 27 to August 22 ..	7	29·6443	6	29·9141	7	29·8235	7	29·9007
August 23 to Sept. 19 ..	7	29·7293	7	29·2593	7	29·6635	7	29·1814
Sept. 20 to October 16 ..	6	29·5291	7	29·6064	7	29·8650	7	29·7078
October 17 to Nov. 13 ..	7	29·9271	6	30·3333	7	29·8193	8	29·5800
Nov. 14 to Dec. 10	6	29·7666	6	29·7033	8	29·4881	7	29·9250
December 11–23	7	29·3928	6	29·1758				
368 days.	91	29·7672	92	29·7347	91	29·7626	94	29·8158
Dec. 24, 1839 to Jan. 6, 1840.	..	....	..	....	7	29·6443	7	29·8007
Jan. 7 to Feb. 2........	7	30·1457	6	29·5441	7	29·1057	7	29·3843
Feb. 3 to March 1......	7	29·2600	6	29·6741	7	30·2893	8	30·4575
March 2–28	6	30·5041	6	30·3100	8	30·1956	7	30·1607
March 29 to April 24 ..	7	29·8300	6	29·9783	7	30·0000	7	30·1857
April 25 to May 22	7	30·2485	6	29·9866	7	29·5728	8	29·8018
May 23 to June 18	7	29·8378	6	29·9566	6	29·8183	8	29·6793
June 19 to July 15	7	29·7450	6	29·8216	7	29·4428	7	29·9164
July 16 to August 11 ..	7	29·5493	6	29·7825	7	30·0328	7	29·8500
August 12 to Sept. 8....	7	29·3700	7	29·7614	6	29·9975	8	29·7575
Sept. 9 to October 5....	6	29·5616	7	29·5057	7	29·5185	7	29·9457
October 6 to Nov. 1	7	30·2550	6	29·8550	7	29·7407	7	29·2628
November 2–29........	7	28·8143	6	29·7575	7	29·4371	8	30·1068
Nov. 30 to Dec. 19.	7	30·0857	6	29·7833	7	30·0185		
362 days.	89	29·7851	80	29·7474	97	29·7724	96	29·8699
Dec. 20–26, 1840	..	....	..	....	..	....	7	30·2678
Dec. 27, 1840 to Jan. 22, 1841..........	7	30·0185	6	29·4708	7	29·3257	7	29·8750
January 23 to Feb. 18 ..		30·0085	6	30·1100	7	29·7057	7	29·3535
February 19 to March 18.	7	30·0443	6	29·5758	6	30·0541	8	29·8550
March 19 to April 14 ..	7	29·5207	6	29·5158	7	29·4850	7	29·7793
April 15 to May 11	7	29·7350	6	29·6400	7	29·7907	7	29·6650
May 12 to June 8	7	29·7293	7	29·7757	6	29·9175	8	30·0050
June 9 to July 5	7	29·8428	6	29·6700	7	29·6671	7	29·8614
July 6 to August 1	7	29·5471	6	29·6833	7	29·7371	7	29·6093
August 2–28	7	29·5057	7	29·5414	6	29·8050	7	29·9543
August 29 to Sept. 25 ..	8	29·6656	6	29·7008	7	29·7850	7	29·6114
Sept. 26 to Oct. 22	7	29·2443	6	29·0675	7	29·4378	7	29·5014
October 23 to Nov. 18 ..	7	29·3571	7	30·0778	6	29·9675	7	29·2857
Nov. 19 to Dec. 15	8	29·4881	6	29·0433	7	29·3657	6	29·3708
December 16–23	8	29·3762						
369 days.	102	29·6488	81	29·6055	87	29·6957	99	29·7139

XXI. *Contributions to the Chemistry of the Urine.* PART II.—*On the Variations in the Alkaline and Earthy Phosphates in Disease. By* HENRY BENCE JONES, *M.A., Fellow of the Royal College of Physicians. Communicated by* THOMAS GRAHAM, *Esq., F.R.S., &c.*

Received January 22,—Read April 2, 1846.

On the Variations in the Earthy and Alkaline Phosphates in Disease.

THE object of the following experiments was to show to what extent the amount of phosphatic salts was increased in disease. Unexpectedly, during the investigation the diminution of the amount became of equal interest. I have found no analyses undertaken for the solution of these questions, some of Sir C. SCUDAMORE's alone being excepted; and these are so made that it is impossible to compare them with those which will here be given.

Though Dr. PROUT long since remarked that excess of phosphates accompanied some affections of nervous structures, yet no analytical results were stated, and the observation seems to have referred to the earthy phosphates alone.

I have in vain as yet sought for some immediate method for approximately determining the total amount of phosphatic salts in the urine. An analysis, requiring five or six hours to perform, is at present the only satisfactory process which can be recommended. Most of the following experiments were made on the water first passed in the morning, and before food: occasionally this could not be obtained, and then the night or afternoon water was taken. Almost all the cases were in St. George's Hospital, and therefore under nearly the same circumstances, as far as exercise was concerned. The diet usually varied with the state of the patient. The details of the cases would extend beyond the limits of the present paper.

Had it been possible, I should have much preferred to make my experiments on the total quantity of urine passed during the twenty-four hours, by which means, measuring the quantity, the total amount of phosphates thrown out of the body would have been known; but I found it utterly impossible to obtain any approach to accuracy in regard to the quantity of water passed in the twenty-four hours. The results would have been so valuable, that it was only when I found by experience how uncertain and inaccurate they must be, that I gave up the plan I had formed. Instead of giving the quantity of phosphatic salts in 1000 parts of urine, of certain specific gravity, it may be thought that a comparative view would have been better taken by calculating the solid residue in each case, from some of the various tables which give the amount of solid residue in 1000 parts of urine of all specific gravities. But no tables admit of this calculation. They may perhaps be true for the total quantity of water in twenty-four hours; but they are not so for the water made at any one period of the day. The water made before and after dinner, for instance, may have the same specific gravity, but the total quantity of solid residue in each may be entirely different. If the urine was a solution of any single substance such tables would be useful, but where there are many substances present in varying quantities at different periods, these formulæ are inapplicable.

In my previous paper I have shown, that in the healthy state the amount of earthy phosphates precipitable by ammonia depends chiefly on the amount of earthy matter taken into the body; the amount varying from ·40 per 1000 urine, specific gravity 1027·9, to 1·49 per 1000 urine, specific gravity 1030.

I have also shown that the alkaline phosphates vary from 7·56 per 1000 urine, specific gravity 1027·9, to 5·77 per 1000 urine, specific gravity 1030.

In the following paper I shall attempt to show that the earthy phosphates are subject to such great variations, depending on the water, the food, and the medicine even, that from their estimation alone no result can be arrived at. I shall then give the total amount of earthy and alkaline phosphates in diseases, in which the nervous tissues, or their neighbouring tissues, are affected.

1. In diseases of the spine; from accidents, caries, paraplegia.
2. In diseases of the membranes and chronic diseases of the brain.
3. In fractures of the bones of the skull.
4. In acute diseases of the brain.
5. In functional diseases of the brain; as violent delirium and delirium tremens.
6. In insane patients.

I shall lastly, for comparison, give the amount of earthy and alkaline phosphates in some diseases in which the nervous tissues may be considered as unaffected.

1. In acute diseases; as acute rheumatism, gout, fever.
2. In chronic diseases, as Bright's disease; diseases in which very small quantities of water are secreted; scrofulous diseases, exostosis and mollities ossium.

TABLE I.—On the Variations of the Earthy Phosphates.

	Earthy phosphates.	Specific gravity.
Case 1. Water passed about 12 o'clock during ten successive days, in a severe case of concussion of the brain from a fall.		
3rd day. No food	·97 per 1000 urine.	1013·2
4th day. No food	·36	1014·5
5th day. No food	·74	1011·4
6th day. No food	1·07	1019·3
7th day. No food	1·28	1019·1
8th day. Some food	·85	1017·5
9th day. More food	1·10	1018·3
10th day. More food	1·05	1020·1
11th day. More food	·52	1010·8
12th day. More food	1·96	1021·9
Case 2. Water passed in the afternoon by a patient with pain in the head and epileptic fits (chronic).		
About 40th day. After salts and senna	2·93	1026·2
51st day	1·55	1015·6
73rd day	1·47	1025·7
90th day	1·35	1023·7
Case 3. Severe pain in the head (chronic).		
About 60th day, afternoon	2·03	1018·5
63rd day	·53	1010·1
Case 4. Inflammation of the brain (acute).		
20th, afternoon	1·15	1031·8
26th day. Died.		
Case 5. Tetanus. Afternoon	1·35	1026·5
Case 6. Delirium tremens	1·21	1030·4

Hence from Case 1, the variations in the earthy phosphates during ten successive days appear to follow no rule. Case 2 has been mentioned in the previous paper as showing the effect of sulphate of magnesia. From the other cases the amount of earthy phosphates seemed to be about the healthy standard. The general conclusion is, that the variations in the earthy phosphates are independent of the nature of the disease; and this conclusion will be found to be confirmed by the subsequent experiments.

TABLE II.—On the Total Amount of Earthy and Alkaline Phosphates in those Diseases in which the Nervous Tissues, or their neighbouring tissues, are affected. And first of Disease of the Spine, from accidents, caries, paraplegia, &c.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. Fractured spine, seventh cervical vertebra.				
2nd day	·12 per 1000 urine.	1023·1	3·71	3·83
3rd day	·41	1017·6	2·29	2·70
8th day	·67	1022·0	7·76	8·43
9th day	·67	1023·1	7·47	8·14
16th day	·41	1011·4	3·43	3·84
18th day	·53	1010·6	3·13	3·66
21st day. Died.				

TABLE II. (Continued.)

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 2. Fractured spine, eleventh dorsal vertebra.				
2nd day	·86 per 1000 urine.	1029·2	8·35	9·21
4th day	·94	1025·9	8·00	8·94
5th day	·75	1025·0	8·04	8·79
7th day	·56	1022·8	5·17	5·73
12th day	·15	1007·8	1·29	1·44
36th day. Died.				
Case 3. Recent paraplegia.				
14th day. Water passed from evening to morning	2·15	1026·5	5·88	8·03
19th day	·70	1016·6	1·34	2·04
22nd day	1·09	1017·9	2·00	3·09
27th day	1·00	1021·3	2·56	3·56
34th day	1·13	1019·4	3·14	4·27
59th day	1·45	1019·9	2·39	3·84
109th day	1·31	1021·2	2·86	3·17
Case 4. Recent paraplegia. Head long slightly affected.				
19th day, afternoon water	2·00	1023·2	1·78	3·78
24th day, morning water	·53	1012·6	3·34	3·87
Case 5. Paralysis from arsenic almost complete.				
20th day	......	1008·6	......	1·69
21st day	·60	1014·8	3·96	4·56
Case 6. Chronic paraplegia (three months)	1·13	1019·4	3·56	4·69
Case 7. Chronic paraplegia (five months)	·49	1015·9	1·51	2·00
Case 8. Paraplegia (seven or eight years' curvature) twelve months	·30	1007·5	·84	1·14
Case 9. Paraplegia. Tabes?	·44	1012·2	·35	·79

In Case 1, on the eighth and ninth day, a slight excess is observable. This is also present in Case 2 on the second, fourth and fifth day; and in chronic cases the quantity of phosphatic salts is, if anything, lower than natural.

TABLE III.—On the Total Amount of Earthy and Alkaline Phosphates in Diseases of the Membranes, and in some Chronic Diseases of the Brain.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. Scalp wound, doing well. On the 16th day from accident, acute inflammation of the membranes began.				
3rd day of inflammation	·56 per 1000 urine.	1022·4	3·94	4·50
4th day	·58	1020·1	5·07	5·65
5th day. Died.				
Case 2. Scalp wound. On the 18th day acute inflammation of membranes began.				
5th day of inflammation	·15	1025·3	6·17	6·32
7th day. Died.				
Case 3. Scalp wound. On the 16th day diffuse inflammation of membranes began.				
9th day of inflammation	·10	1011·5	2·70	2·80
11th day	·09	1008·0	1·96	2·05
Case 4. Two years' chronic disease of the bones and membranes	1·25	1017·4	2·60	3·85
Case 5. Pain in the head, ending in total blindness at last.				
30th day	·27	1021·3	·69	·96
35th day	·33	1010·1	·27	·60
54th day	·74	1015·2	2·33	3·07
71st day	·56	1006·0	·32	·88
82nd day	·13	1010·0	1·30	1·43
89th day	·93	1011·2	2·42	3·35
359th day. Died of softening of the brain.				

TABLE III. (Continued.)

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 6. 4th day. Slight paralysis of fifth nerve	·76	1012·6	·46	1·22
Case 7. 4th day. Recent hemiplegia	·75	1010·2	1·14	1·89
14th day. Recovered.				
Case 8. 3rd day. Recent hemiplegia	1·84	1027·0	4·50	6·34
Case 9. Diabetes, effusion in brain. Sugar in effused fluid	1·70	1033·9	1·58	3·28

In the acute inflammation of Case 1 and 2 no increase of phosphates is observed. The marked chronic attack in Case 5 shows, if anything, a deficiency. Slight cases of paralysis show no increase.

TABLE IV.—On the Total Amount of Earthy and Alkaline Phosphates in cases of Fractures of the Bones of the Skull.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. Fracture of the base of the skull.				
3rd day	2·09 per 1000 urine	1030·0	7·20	9·29
5th day	1·74	1021·3	2·60	4·34
8th day	1·66	1019·6	5·00	6·66
14th day	·60	1020·0	1·51	2·11
18th day. Rigor, pain in the head	1·34	1021·2	8·63	9·97
21st day. Acute pain in side	·61	1019·1	2·69	3·30
23rd day. Excessive pleurisy	·75	1016·9	3·19	3·94
26th day	·15	1022·2	1·05	1·20
31st day	·73	1024·8	6·26	6·99
50th day. Acute pericarditis	·73	1027·3	3·74	4·47
118th day. Recovered	·38	1018·3	3·31	3·69
Case 2. Fracture of the base of the skull.				
4th day	·13	1026·3	9·40	9·53
5th day	·27	1026·5	10·43	10·70
6th day. 32 ℥ passed	·30	1022·8	7·61	7·91
7th day	·15	1024·7	4·67	4·82
9th day. Erysipelas	·12	1017·6	4·12	4·24
15th day	·57	1018·5	3·43	4·00
32nd day. Went out well.				
Case 3. Fracture of frontal bone.				
2nd day	·36	1026·4	4·81	5·17
7th day	·72	1019·3	3·12	3·84
Case 4. Fracture of the base of the skull.				
2nd day	·52	1028·6	3·50	4·02
4th day	1·24	1029·8	5·89	7·13
7th day	·71	1017·5	4·11	4·82

In Case 1, on the 3rd and 18th day, when the head symptoms were most marked, the phosphates were above the average. In the same case, when other acute inflammations supervened, as on the 23rd and 50th day, no increase was observed. In Case 2 also, on the 4th, 5th and 6th days, when the head symptoms were urgent, the total amount of phosphates was considerably above the average; on the 9th day, when erysipelas came on, no increase was seen. In this case the earthy phosphates are worthy of note. Cases 3 and 4 were severe fractures, but without acute symptoms.

TABLE V.—On the Total Amount of Earthy and Alkaline Phosphates in acute Diseases of the Brain.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. Acute inflammation of the brain.				
12th day	1·82 per 1000 urine.	1029·7	11·33	13·15
14th day	2·31	1033·0	9·80	12·11
16th day	1·35	1030·0	8·18	9·53
18th day. Died.				
Case 2. Acute inflammation.				
16th day	·90	1025·3	5·93 5·93	6·83
17th day	1·48	1028·1	8·31 8·43	9·79 9·91
19th day	1·02	1024·8	7·41	8·43
20th day. 58℥	·98	1021·2	4·79	5·77
21st, morning. 24℥	·62	1016·9	3·63	4·25
21st, night. 14℥	1·10	1024·6	5·98	7·08
22nd day. Died.				
Case 3. Acute disease; apoplexy, paralysis.				
22nd day	1·52	1021·6	6·52	8·04
23rd day	1·66	1023·1	4·43	6·09
24th day	2·08	1032·7	7·48	9·56
27th day	1·48	1026·9	4·56	6·04
28th day	1·35	1025·4	4·07	5·42
33rd day. 26℥ water	·68	1018·6	1·47	2·15
34th day. 18℥ water	1·05	1024·3	4·94	5·99
96th day. Went out in a state of dementia.				
Case 4. Acute inflammation supervening on chronic disease.				
21st day of severe symptoms	1·89	1031·1	11·49	13·38
23rd day	1·67	1022·9	4·36	6·03
30th day	1·44	1016·3	1·35	2·79
Went out relieved.				
Case 5. Acute hydrocephalus. Three years old. Died.		....	....	6·41

In Case 1 the symptoms were most strongly marked. In Case 2 there was a doubt whether the symptoms were to be attributed to typhoid fever or to affection of the brain. The progress of the case and the examination showed the inflammation of the nervous tissues. Case 3 was more chronic, but with acute symptoms occasionally. Case 4 yielded to very active treatment.

TABLE VI.—On the Total Amount of the Earthy and Alkaline Phosphates in some functional Diseases of the Brain.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. Violent delirium, with erysipelas on the third day after scalp wound.				
4th day of erysipelas	·30 per 1000 urine.	1026·2	8·69	8·99
Case 2. Violent delirium. Mania? Abscess of the neck.				
10th day	·90	1025·9	8·16	9·06
13th day	·90	1025·4	5·72	6·62
16th day	·30	1010·8	1·22	1·52
Case 3. Last day of phthisis. Raving. Urine very scanty	·63	1025·6	7·91	8·54

TABLE VI. (Continued.)

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 4. Intense delirium. Epileptic fits continually.				
2nd day	2·21 per 1000 urine.	1022·6	7·75	9·96
3rd, morning	2·56	1024·8	12·19	14·75
3rd, night	2·15	1023·7	12·23	14·38
4th, night	2·71	1022·8	9·39	12·10
5th, night	1·53	1019·4	·34 ·28	1·87 1·81
6th, night	·74	1020·5	5·16	5·90
9th, night	......	1021·4	....	3·93
12th, night	·15	1020·2	2·93	3·08
25th, night. Died.				
Case 5. Seven days' continued fever; excessive delirium	·24	1017·8	5·43	5·67
Case 6. Continued fever, muttering delirium.				
14th day	·41	1026·0	4·37	4·78
16th day	·37	1022·0	1·89	2·26
19th day	·10	1009·2	2·53	2·63
Case 7. 6th day. Delirium tremens. Urine very scanty. Recovered.		1028·7	....	1·07
Case 8. 4th day. Delirium tremens. 4℥ water.	·19	1019·1	2·21	2·40
5th day. 7℥ water	·04	1019·3	·11 ·08	·15 ·12
6th, morning. 6℥ water	......	1017·9	....	·06
6th, evening. 6℥ water	......	1019·7	....	·24
6th, night. Died.				
Case 9. 5th day. Delirium tremens	·10 ·09	1018·0	0·00	·10 ·09
6th day. Taking food	·79	1022·5	5·31	6·10
8th day	......	1027·9	....	8·41
9th day. Well	·90	1022·9	6·07	6·97
25th day. Remained in for injury	·42	1010·9	1·01	1·43
Case 10. 4th day. Delirium tremens	·45	1024·0	3·13	3·58
7th day. Recovering	·72	1025·3	5·81	6·53
Case 11. 5th day. Delirium tremens, slight	·89	1021·6	5·45	6·34
6th day. Recovering	·77	1019·1	3·41	4·18
Case 12. 2nd day. Delirium tremens, slight	·56	1019·6	4·13	4·69
Case 13. 6th day. Delirium tremens	......	1011·0	....	2·07

In this Table are placed those cases which from their symptoms or post-mortem appearances could not be affirmed to be inflammations of the brain. Case 4 was most remarkable: the violent symptoms abated on the 5th day; but the post-mortem examination on the 26th day showed no positive marks of inflammatory action. On this account I have placed it in the class of functional diseases: further experiments may ultimately show, that the great increase in alkaline phosphates alone is sufficient to indicate the nature of the disease. In Cases 5 and 6 no excess of phosphates is observable. The 5th and 6th days of Case 8 are particularly remarkable. The 6℥ of water on the 6th morning were strongly acid to test-paper, and remained so for eight days in June. Case 9; the 5th day was most remarkable, as no alkaline phosphate was present: the urine was acid to test-paper. In the other cases of delirium tremens, when food could be taken, the phosphates did not appear to be much affected.

Table VII.—On the Total Amount of Earthy and Alkaline Phosphates in Insane Patients.

For the opportunity of seeing and examining these cases I am indebted to Dr. Alexander Sutherland, who allowed me to choose among his patients in St. Luke's Hospital those cases which I thought to be most suitable.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. General paralysis. Early case	1·50 per 1000 urine.	1028·6	5·40	6·90
Same case	1·17	1023·3	2·97	4·14
Case 2. General paralysis. Early case	·79	1022·0	1·23	2·02
Case 3. General paralysis. Early case	·41	1016·6	5·36	5·77
Case 4. General paralysis. Early case	......	1018·3	......	1·30
Case 5. Extreme case. Paraplegia. Many years.	......	1006·7	......	1·35
Case 6. Mania	·42	1023·3	4·38	4·70
Case 7. Mania; acute paroxysm	1·32	1029·3	7·58	8·90
Same patient convalescent	·67	1020·0	2·44	3·11
Case 8. Mania. Some months	......	1025·9	......	1·26
Case 9. Mania. Four months	·74	1015·3	·38	1·12
Four months and a half	·72	1015·9	·46	1·18
Case 10. Melancholia	·67	1024·3	3·36	4·03
Case 11. Melancholia	......	1011·3	......	2·71
Case 12. Melancholia	·71	1025·9	3·08	3·79
Case 13. Melancholia. Recent	1·47	1027·9	2·34	3·81
Case 14. Senile dementia	·71	1021·0	2·10	2·81

In the five cases of general paralysis no increase of the total amount of phosphates is observed. Case 7, during an acute paroxysm of mania, shows a slight increase in the total amount of phosphates. Case 8 and 9, also of mania, appear more to approximate to the state of urine in delirium tremens. The cases of melancholia present nothing remarkable.

Table VIII.—On the Total Amount of Earthy and Alkaline Phosphates in Diseases, in which the Nervous Tissues, or their neighbouring tissues, are not affected.

1. In some acute diseases.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. 5th day. Inflammation from crushed arm	·60 per 1000 urine.	1024·8	5·57	6·17
Case 2. 6th day. Acute rheumatism; 2nd day, pericarditis	·73	1026·6	5·79	6·52
Case 3. 4th day. Acute rheumatism	·78	1023·7	4·07	4·85
Case 4. 8th day. Acute rheumatism	1·28	1023·9	3·63	4·91
Case 5. 11th day. Acute rheumatism; 1st day, pericarditis	·45	1010·2	1·65	2·10
Case 6. Acute rheumatism	·09	1016·7	2·91	3·00
Case 7. Acute gout	·60	1015·1	2·50	3·10
Case 8. Acute gout	......	....	......	3·06
Case 9. 2nd day, of erysipelas; slight	·33	1016·6	2·48	2·81
Case 10. 4th day, of scarlet fever	·33	1010·4	1·19	1·52
Case 11. 2nd week, of petechial fever	·38	1011·8	1·84	2·22

These cases of acute inflammation and fevers show no increase in the total amount of phosphatic salts.

Table IX.—On the Total Amount of Earthy and Alkaline Phosphates in Diseases, in which the Nervous Tissues, or their neighbouring Tissues, are not affected.

2. In some chronic diseases.

	Earthy phosphates.	Specific gravity.	Alkaline phosphates.	Total.
Case 1. Probable congestion of the kidneys only	·85 per 1000 urine.	1026·4	4·68	5·53
Case 2. Bright's disease, six months. Acute inflammation of abdomen	·34	1028·0	6·59	6·93
Case 3. Bright's disease, thirteen weeks	·15	1018·1	3·15	3·30
Case 4. Bright's disease, two months and a half. Acute pericarditis; 2nd day	·12	1012·6	1·31	1·43
Case 5. Bright's disease; four months. Recovering	·15	1008·5	1·68	1·83
Case 6. Bright's disease; three weeks...........	·75	1018·6	2·94	3·69
Case 7. Bright's disease without dropsy. Paraplegia, 2nd day	·39	1006·1	·37	·76
12th day	·15	1007·7	1·07	1·22
23rd day. Comatose	·08	1010·0	·89	·97
Case 8. Ascites-jaundice; eleven weeks. Very scanty urine..	1·05	1025·6	8·43	9·48
Case 9. General dropsy, 21st day. Urine very scanty	·67	1019·2	7·11	7·78
23rd day	·99	1019·9	4·67	5·66
Case 10. Phthisis; seven months. Urine very scanty	·45	1017·6	5·64	6·09
Case 11. Phthisis languid; three months	·21	1013·9	1·31	1·52
Case 12. Schirrus pylorus. Excessive wasting for eighteen months	·41	1012·3	3·61 3·55	4·02 3·96
Case 13. Diabetes mellitus	......	1043·2	......	2·66
Case 14. Scrofulous abscess........................	1·05	1021·8	3·54	4·59
Case 15. Scrofulous abscess; three years	......	1027·7	......	4·62
Case 16. Scrofulous abscess; four years.........	......	1022·5	......	5·07
Case 17. Scrofulous abscess: two years	......	1020·4	......	4·35
Case 18. Scrofulous abscess; one month.........	·30	1019·5	2·48	2·78
Case 19. Chorea, chronic	·15	1008·2	2·43	2·58
Case 20. Exostosis; severe	1·12	1026·5	4·65	5·77
Same case	·75	1020·0	4·81	5·56
Same case	·66	1018·9	5·58	6·24
Case 21. Mollities ossium; extremely acute case, November 2.	......	1043·2	......	5·68
November 17	1·20	1039·6		
December 27	1·43	1031·3	6·62	8·05
December 29	1·57	1037·9	6·67	8·24
December 30	1·72	1042·7	10·13	11·85
January 2. Died.				
Case 22. Mollities ossium; very chronic case...	·64	1020·2	3·74	4·38
A month afterwards	·46	1016·5	4·70	5·16

The first seven cases of diseased kidney showed no increase, even when acute inflammation was present. In Cases 8, 9 and 10, a very small quantity of urine was secreted, and there is a slight apparent increase in the amount of phosphates. The cases of scrofula were dispensary patients of Mr. Toynbee's, and no increase of phosphates is observable in them. The case of exostosis was a very extreme case, and the phosphates are in about the healthy proportion. The first case of mollities was a still more severe one: there is a decided increase in the earthy phosphates; and the alkaline phosphates at the last were also in excess, though there was no symptom whatever of affection of the nervous structures.

The conclusions I have drawn may be thus enumerated:—

Table I.—The variations in the earthy phosphates in one case, during ten successive days, appear to follow no rule. In the other cases the amount of earthy phosphates seemed to be about the healthy standard.

The general conclusion was, that the variations in the earthy phosphates were independent of the nature of the disease; and this conclusion is borne out by all the other tables.

Table II.—In fractures of the spine and paraplegia, the total amount of phosphatic salts was slightly above the healthy standard at the early period, when inflammatory action might be present; when chronic, or free from inflammation, the total quantity of phosphatic salts was lower than natural.

Table III.—In chronic diseases of the brain, and in chronic, and even acute diseases of the membranes, there was no increase of phosphates.

Table IV.—In fractures of the bones of the skull, when any inflammation of the brain appeared, there was a slight increase in the total amount of phosphates. When there were no head symptoms no increase of phosphates was observed, even though other acute inflammations supervened.

Table V.—In acute inflammation of the brain there was an excessive amount of phosphates secreted: when the acute inflammation became chronic no excess was observable.

Table VI.—In some functional diseases of the brain an excessive amount of phosphates was secreted; this ceased with the delirium. In other functional cases, as in fevers, no excess was observed. Delirium tremens showed no excess or deficiency when food could be taken; but in the most violent cases, when no food was taken, the phosphates were diminished in a most remarkable degree. In one case in which, at this period, there was no alkaline phosphate, the urine was acid to test-paper. In another, in which the total quantity of phosphatic salts =·06 per 1000 urine, there was a strong acid reaction: the urine remained acid for eight days in June.

Table VII.—In the general paralysis of the insane no increase of phosphates was observed. One case of acute paroxysm of mania showed a small increase during the paroxysm. In two other cases of mania there appeared a diminution of phosphates approaching to that in delirium tremens.

Table VIII.—Acute inflammations and fevers showed no increase.

Table IX.—Bright's disease, even with acute inflammation, showed no increase. Where only a few ounces of urine were secreted, as in dropsy, there was a slight apparent increase. In scrofulous diseases no increase was observed, nor in a very extreme case of exostosis. In the acute case of mollities ossium there was a decided increase in the earthy phosphates, and the alkaline phosphates at last were also in excess, though there was no symptom whatever of affection of the nervous structures.

The general conclusions are:—

1. That acute affections of nervous substance, organic and functional, are the only diseases in which an excess of phosphatic salts appears in the urine. In acute inflammation of the brain, the amount of phosphates seems to be proportional to the intensity of the inflammation. In some states of violent delirium the amount of phosphates may also be proportional to the delirium.

2. That in a large class of functional diseases of the brain, of which delirium tremens presents the most marked examples, the amount of phosphates is most remarkably diminished.

3. That no chronic diseases whatever show any marked excess in the total quantity of phosphatic salts secreted, at least as far as this mode of analysis is conclusive. One case of mollities ossium formed the only exception to these rules.

XXII. *Remarks on the Extractive Material of Urine, and on the Excretion of Sulphur and Phosphorus by the Kidneys in an unoxidized state. By* EDMUND RONALDS, *Ph.D., Giessen. Communicated by* GOLDING BIRD, *A.M., M.D., F.R.S., &c.*

Received April 25,—Read June 18, 1846.

SOME months back, at the instigation of Dr. GOLDING BIRD, I undertook some experiments to ascertain whether, in cases of diseased and imperfect function of the lungs or liver, when the normal quantity of carbon could not be discharged from the system by those channels, the kidneys undertook an extra duty, and whether under such circumstances an excess of carbon could be shown in the urine above that usually secreted under healthy conditions.

Should this question be answered in the affirmative, and should it be found that a larger amount of carbon was excreted by the urine in persons affected with such diseases, a practical application might reasonably be made of the fact. For by stimulating the kidneys to still greater exertion, the amount of work required of the lungs or of the liver could be lessened, and thus a better chance offered them of being restored to a healthy state.

The method proposed for solving this problem was, to precipitate the urine of different patients suffering from diseases of the kinds mentioned, with basic acetate of lead, keeping it slightly alkaline by the addition of a few drops of ammonia, then to ascertain the amount of organic matter contained in the precipitate, and in particular the amount of carbon, and lastly to compare these quantities with those obtained in a similar manner from the urine of healthy individuals.

In endeavouring to determine the amount of organic matter in the lead precipitate by burning, as likewise in determining the quantity of carbon by an elementary analysis of the same precipitate with oxide of copper, results were obtained which did not agree, and many difficulties arose which it is not necessary to state now, but which rendered it absolutely necessary to separate by some means the organic matter from the oxide of lead before submitting it to analysis, and even that we might obtain accurately its quantity. Whilst employed in seeking an accurate mode of separation, Dr. SCHERER's paper appeared on the extractive matters of urine*, in which a successful mode of separation is described, and the question at issue answered. Dr. SCHERER finds that the extractive or colouring matter of the urine contains a larger quantity of carbon and hydrogen when obtained from persons in whom the normal function of the lungs, of the liver or of the skin is deranged, than when taken from healthy subjects, and that the same excess of carbon passes off by the urine when the diet is more than usually rich in that element. From his paper however it does not appear that the quantity of this extractive or colouring matter passed during a certain space of time has been ascertained, and it strikes me that he assumes the quantity of extractive to be the same in all kinds of urine; this I think requires to be proved before it can be positively affirmed that more carbon and hydrogen do pass off by the urine in such diseased conditions, as a larger quantity of less highly carbonized extractive matter might compensate for the excess of carbon in the more highly carbonized, supposing the latter to be in less quantity. The relative quantity of these matters, and likewise the relative quantities of urea in a certain amount of urine, must be accurately determined before the conclusion can be considered as absolutely proved.

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* Annalen der Chem. und Pharm. lvii. 180.

Whilst engaged with the foregoing researches, it occurred to me that it might not be devoid of interest to the physiologist to know the amount of sulphur which was secreted by the kidneys in an unoxidized state. That urine does contain sulphur, not in combination as sulphate, is evident from the smell of sulphuretted hydrogen which, mixed with that of ammonia, is evolved from it whilst undergoing spontaneous decomposition, also from the blackening which white lead paint suffers when exposed to the gases arising from putrid urine, and likewise from the fact, that urine allowed to putrefy in a glass vessel containing oxide of lead as one of its contituents, permanently blackens the glass. To set the fact beyond doubt, two portions of urine, previously deprived of mucus by acetic acid and filtration, each consisting of four fluid ounces, were measured; the one simply evaporated and burnt, the other evaporated and afterwards deflagrated with nitre. Each portion was then dissolved in dilute nitric acid, leaving a minute insoluble residue, and the sulphuric acid precipitated by chloride of barium; the results were as follows:—

Four fluid oz., simply incinerated, gave

$$\begin{array}{lrlr} & \text{grs.} & & \text{gr.} \\ \text{BaO SO}_3 & 2{\cdot}656 = & \text{SO}_3 & 0{\cdot}902 \\ & = & \text{S} & 0{\cdot}366. \end{array}$$

Four fluid oz., deflagrated with nitre, gave in grains

$$\begin{array}{lrlr} \text{BaO SO}_3 & 5{\cdot}697 = & \text{SO}_3 & 1{\cdot}954 \\ & = & \text{S} & 0{\cdot}783. \end{array}$$

The quantity of sulphur in four fluid ounces not excreted in the state of sulphate was therefore 0·417 grain. To ascertain the quantity of sulphur excreted by the urine in twenty-four hours in an unoxidized state, the whole quantity passed by three individuals during that time was collected on different days and measured; its specific gravity was taken, and after being filtered from mucus, two portions of each specimen were measured in a specific-gravity bottle containing 1000 grain measures; one portion was simply acidified with nitric acid, and the sulphuric acid precipitated by nitrate of barytes. The other portion was evaporated with nitre and deflagrated, and the fused mass treated with dilute nitric acid and nitrate of barytes. From the difference in the quantities of sulphate of barytes obtained, the amount of sulphur not in an oxidized state was ascertained. The results from five different experiments are shown by the following Table.

TABLE, showing the relative proportions of Sulphur free and combined with oxygen excreted by the kidneys in twenty-four hours.

Quantity of urine in 24 hours.	58 fluid-ounces.		41·5 fluid-ounces.		62·5 fluid-ounces.		56 fluid-ounces.		43·5 fluid-ounces.	
Specific gravity.	1·014.		1·019.		1·017.		1·022.		1·016.	
	In 1014 grs.	In 100 grs.	In 1019 grs.	In 100 grs.	In 1017 grs.	In 100 grs.	In 1022 grs.	In 100 grs.	In 1016 grs.	In 100 grs.
Sulphate of barytes from the acid existing in the urine...	3·1658	0·312	4·354	0·427	4·215	0·414	7·314	0·715	3·922	0·386
Sulphate of barytes precipitated after oxidation of the free sulphur..................	4·4784	0·441	5·744	0·563	5·559	0·546	8·447	0·826	5·158	0·507
Quantity of unoxidized sulphur..........................	0·18	0·017	0·19	0·018	0·183	0·018	0·157	0·0153	0·168	0·0165
Free sulphur excreted in 24 hours	4·639		3·715		4·998		3·866		3·247	

It thus appears that from three to five grains of sulphur pass off daily by the urine in some other combination than as sulphuric acid, and that these three to five grains amount to about one-fourth of the whole quantity of sulphur excreted by the kidneys. With a view to ascertain what compound contained this sulphur in the urine, I have examined the precipitates produced in urine by neutral and basic acetate of lead, after the separation of the sulphates by baryta, and find that they only contain traces of sulphur. The colouring matter described by SCHERER, and obtained by the method he adopts, likewise contains only a trace; whereas the liquid containing the urea, generally considered free from all other organic matter, which remains on the separation of the precipitate by basic acetate of lead, contains nearly the whole of this excess of sulphur, but how combined I have not yet been able to ascertain. The determination of this question, which I propose to examine, may possibly lead to some interesting facts, and perhaps throw some light upon the question respecting the formation of cystic oxide.

From some preliminary experiments made for the purpose of ascertaining whether phosphorus was contained in urine in any other compound than as phosphate, the following results were obtained.

To the four ounces of urine employed for the preliminary determination of the sulphuric acid and sulphur in the former experiment, after the precipitation of the sulphuric acid by barytes, some more nitrate of barytes was added and then the whole carefully neutralized with ammonia. The following quantities were obtained:—

Phosphate of barytes obtained from the PO_5 naturally contained in urine was	Phosphate of barytes obtained from urine after deflagration with nitre was
$BaO\,PO_5$ 5·775 grains	$BaO\,PO_5$ 6·532 grains
$=PO_5$ 1·834	$=PO_5$ 2·074
$=P$ 0·805;	$=P$ 0·910;

showing an excess of phosphorus over that contained as phosphate in the four ounces of urine to be 0·105 grain.

In another experiment, in which the same portions of urine were employed as at the fifth column of the foregoing Table, the following were the results:—

Phosphate of barytes obtained from the PO_5 naturally contained in 1016 grs. of urine.	Phosphate of barytes obtained from 1016 grs. of urine after deflagrating with nitre.
$BaO\ PO_5$ 3·135 grains	$BaO\ PO_5$ 5·313 grains
$=PO_5$ 0·993	$=PO_5$ 1·687
$=P$ 0·435.	$=P$ 0·740.

Therefore 0·305 grain of phosphorus was contained in the 1016 grains of urine in an unoxidized state, which, calculated for the whole amount of urine passed in twenty-four hours, would amount to 5·896 grains. In some other specimens of urine which I examined there was however no approach to this quantity of phosphorus in an unoxidized state, and as the mode of analysis employed in these preliminary experiments was not the most accurate, I intend to make the determination of the quantity of phosphorus the subject of further experiments.

The only opportunity I have had of examining urine in a diseased state, was a portion obtained from a patient suffering from diabetes mellitus. As might have been anticipated from the character of this disease, the amount of sulphur which the urine contained in an unoxidized state, was considerably greater (by one-fourth) than in healthy urine.

The diabetic urine had a specific gravity of 1046.

Of this urine 1046 grains, precipitated with nitrate of barytes, gave—

4·308 grains sulphate of barytes $=$ 1·479 grain SO_3
$=$0·592 grain S.

After the precipitation of the sulphuric acid by baryta, the urine was evaporated down with nitric acid, mixed with nitre and deflagrated. An excess of nitrate of barytes having been used to precipitate the sulphuric acid, there remained on treating the fused mass with dilute nitric acid, an insoluble residue of sulphate of barytes, the sulphuric acid of which had been derived from the oxidation of the sulphur by the nitre; the sulphate of barytes amounted to

1·837 grain $=$0·629 grain sulphuric acid
$=$0·251 grain sulphur, or 0·024 per cent.,

whilst in healthy urine the sulphur in this state never exceeded 0·018 per cent.

XXIII. *On the Fossil Remains of the soft parts of Foraminifera, discovered in the Chalk and Flint of the South-east of England. By* Gideon Algernon Mantell, *Esq., LL.D., F.R.S., &c.*

Received May 28,—Read June 18, 1846.

THE last communication I had the honour to lay before the Royal Society, related to the organic remains of the colossal extinct Reptiles, which inhabited the dry land, during that remote period when the Wealden strata were deposited. The present notice embraces the consideration of the fossil relics of beings so minute as to be invisible to the unassisted eye, that swarmed in the cretaceous ocean, and of which numerous genera and species have descended through succeeding ages, and constitute a large proportion of the inhabitants of the present seas.

In a microscopical examination of chalk and flint, undertaken for the purpose of testing the accuracy of the statement of M. Ehrenberg, that a considerable portion of the cretaceous strata is composed of minute organisms, I observed that the chambers of the shells of many *Rotaliæ* were filled with a substance, varying in appearance from a dark opaque brown, to a light transparent amber; and resembling in form, the soft bodies of existing species of Polythalamia*. I was particularly struck with the similitude between some of the fossils, and the recent *Nonionina* when deprived of its shell by immersion in diluted hydrochloric acid; and having, by the courtesy of Mr. Williamson of Manchester, procured Rotaliæ from mud dredged up in the Levant, I found among them several that contained the body of the animal partially collapsed, and of a dark brown colour, which presented an analogous appearance. I was therefore led to infer, that the substance filling the cells of the flint Rotaliæ was the remains of the soft parts of the original animalcules, in the state of *molluskite*†.

In a paper read before the Geological Society of London, and published in the Annals of Natural History for August 1845‡, I ventured to suggest this explanation of the origin of the fossils in question; but the conjecture was regarded by certain geologists as "very startling and unsatisfactory;" and as the specimens were enveloped in flint, the appearance was attributed to an infiltration into the empty chambers, of mineral matter of a different colour from the surrounding matrix; a circumstance of common occurrence, not only in Ammonites, Nautili, and other chambered Cephalopoda, but also in Polythalamia, which are frequently filled with chalk, flint, and silicate of iron[*]. The usual appearance of the fossil Rotaliæ filled with chalk, when viewed by transmitted light, and rendered semi-transparent by Canada balsam, is shown in fig. 6.

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* The first flint specimen that came under my notice was discovered by my friend the Rev. J. B. Reade, F.R.S.

† *Molluskite*; a name proposed by the author, (in a paper read before the Geological Society, but not published) for the carbonaceous substance resulting from the soft bodies of testaceous mollusks that abounds in various limestones. See Medals of Creation, p. 431.

‡ Notes of a Microscopical Examination of the Chalk and Flint of the South-east of England, with remarks on the Animalculites of certain Tertiary and modern Deposits.

The unequivocal organic structure, however, discernible in the substance contained in the cells of the Rotaliæ by a highly magnifying power, and of which no traces are observable in the mineral casts, and the identity of appearance in the fossils and the corrugated animal body in the Levant specimens, convinced me of the correctness of the explanation I had suggested. I therefore resolved to follow up the inquiry by an examination of Rotaliæ from chalk, in the expectation, that if the shell were dissolved by acid, indications of the body of the original might be detected in the residuum, in an unmineralized condition. After many fruitless experiments, I succeeded in procuring several examples of the soft bodies of Rotaliæ in an extraordinary state of preservation, from the grey chalk of Folkstone.

To Mr. HENRY DEANE of Clapham Common, an able chemist and microscopical observer, I am indebted for the most illustrative specimens; accurate figures of which, drawn by Mr. MOUNSEY, and M. DINKEL, are subjoined. These relics were obtained by subjecting a few grains of the cretaceous rock to the action of weak hydrochloric acid, by which means the calcareous earth, and the shells it enveloped, were removed; the residue consisted of particles of quartz, and of green silicate of iron, with which the chlorite chalk abounds, and numerous remains of the soft parts of animalcules. A small portion was then prepared in the usual manner with Canada balsam, and this was found to contain many Xanthidia, and the Rotaliæ hereafter described.

I have not had an opportunity of examining the structure of the living Rotaliæ; but from the recent observations of M. EHRENBERG, it appears that the organization of these minute animals is very simple, and has no relation whatever to that of the Cephalopoda, as was formerly conjectured. The body is inclosed within the shell, and occupies not only the outer chamber, but also all the cells *contemporaneously*; and the shell is pierced all over with minute pores like a sieve (see fig. 15), through which tentacula protrude; there are also several soft transparent feelers or *pseudopodia*, which are instruments of locomotion. The shell of the Rotalia, therefore, though presenting the general form and chambered structure of that of the Nautilus, is essentially different; for while in the shell of the latter, the animal occupies only the outer chamber, and all the internal compartments are successively-quitted empty dwellings, in the Polythalamia the body distinctly fills up *simultaneously* all the cells. When the shell is removed by weak hydrochloric acid, the soft body is exposed, and is seen to extend to the innermost chamber; and there is a connecting tube occupying the place of the siphuncle of the Nautilus, but which is the intestinal canal; for the cells of the shell contain the receptacles of the digestive sacs or stomachs, in which minute Infusoria (as Monads, Naviculæ, &c.), that have been swallowed by the animal, may sometimes be observed.

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[*] In these cases, the shells were probably either empty when enveloped in the liquid chalk or flint, or speedily became so by the decomposition of the soft parts; but in the instances under examination, I conceive that the live animal was suddenly enclosed in its shell, and hermetically sealed, as it were, by the investing mineral matter, and thus the usual putrefactive process prevented.

In the fossils, the appearance of the parts which I suppose to be the digestive organs, is that of a series of bladders or sacs, composed of a tough, flexible skin or integument, connected by a tube. These organs are more or less filled with a dark substance; those which are distended are always well-defined, while the empty ones are collapsed and disposed in folds, just as membranous pouches would appear under similar conditions. The sacs regularly diminish in size from the outer to the innermost cell, and vary in number from fourteen to twenty-six; being far more numerous than in the recent species. In some instances small papillæ are observable on the external surface of the integument; these are probably vestiges of the pseudopodia or tentacula.

The specimens to which I would first solicit attention are two Rotaliæ in flint (figs. 8 and 12). In the example, fig. 12, which is seen in an oblique direction, the outline and thickness of the shell and its septa are distinctly visible; as if a longitudinal section had been made through the shell, and the portion nearest the observer removed. Every compartment contains a brown granular substance, and the connecting tube is partially distended with a similar material. In this specimen, either a portion of the shell has been removed by the section of the flint so as to display the internal parts, or it has been transmuted into silex so transparent as to elude observation*. As an object of comparison with this fossil, the shell of a recent species from the Levant, seen by reflected light with a low power, is represented, fig. 15. The general contour of the shell is nearly the same in both; but in the recent example the outer surface remains, and exhibits the characteristic foramina of the genus. In the chalk Rotaliæ the perforations are for the most part obscured by the calcareous investment; but occasionally specimens both of the single and compound Polythalamia are met with, in which they are well-displayed; and in some instances the foramina are filled by a dark material, as if the bases of the tentacula were remaining in the state of molluskite†.

The fossil, fig. 8, is contained in the same atom of flint as that above described. The interior of the animalcule is here completely exposed; the sacs and the intestinal canal are as perfect as in an individual recently dead, and just taken out of the sea. The folds of the sacs that are but partially filled with the brown endochrome, resemble the duplicatures produced by the shrinking, or corrugation, of a flexible integument. The outline of the shell is but dimly visible, and can only be rendered apparent by a peculiar arrangement of the mirror of the microscope; but it is sufficiently defined to show that the sacs occupy their respective chambers. As these two specimens are contained in semi-transparent flint, the appearances described may be supposed to have originated from the soft parts having undergone silicification, the brown endochrome of the original constituting the colouring material; but this hypothesis cannot be applicable to the following examples, all of which are from the Folkstone grey chalk. These are associated with numerous particles of transparent white and green quartz; all vestiges of the shells having been destroyed by the acid. Fig. 5, is the body of a Rotalia deprived of its shell by the process previously described; it consists of fourteen sacs, in their natural position, which are filled with a dark substance, and present no folds or corrugations, as do the empty sacs in other examples. At the part corresponding with the outer compartment, a considerable space is occupied by a pale transparent material, extending in patches beyond and below, and enveloping several dark globular bodies (*a*), that resemble in shape the ova of certain Gasteropoda. That these belong to the same animal seems probable from the occurrence of similar ova (*a, a, a,*) in the fossil represented, fig. 11, which is the body of a Rotalia seen foreshortened in the horizontal plane; in this specimen four large sacs are exposed, and these exhibit in a striking manner the folded condition of the integument of which they are composed. The globular bodies (*ova*?) are twenty-one in number.

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* The Polythalamia which occur in the chalk surrounding sponges inclosed in flint nodules, are frequently in a silicified state, and appear as transparent as glass, under the microscope.

† In the silicified Rotaliæ the foramina are frequently well-displayed.

The examination of the specimens above-described will elucidate the nature of the remarkable fossil delineated in fig. 10; a specimen, to which I would especially refer in confirmation of the opinion, that the appearances described can only have resulted from the preservation of the internal parts of the animalcules in an unmineralised state, like insects in amber; at least no other interpretation occurs to me as affording so satisfactory an explanation of the phenomena under review.

In this example the entire integument of the body of a Rotalia appears to be present, the shell having been wholly removed by the acid. The membrane of the largest sacs is very much corrugated, and disposed in numerous duplications, probably from the empty state of those organs; but the general contour of the original shell is preserved, and the inner subdivisions maintain an involuted discoidal arrangement. Some granules dispersed through a mass of light-brown matter, appear in the upper part of the specimen; and on several of the sacs there are papillæ, which may be regarded as indications of the bases of pseudopodia. The drawing so faithfully represents the original, that further description is unnecessary*. On this fossil I cannot forbear to observe, that this extraordinary preservation of the soft delicate body of an animalcule invisible to the unassisted eye, through the innumerable ages that must have elapsed since the deposition of the chalk in which it was enshrined, is a fact not less remarkable than the occurrence of the carcase of the Lena Mammoth, in the frozen soil of Siberia.

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* The shell of this specimen was probably of the same species as that represented in fig. 6.

In another example (fig. 7), a series of sacs, held together by the connecting tube, is uncoiled as it were, and extended in a longitudinal direction ; proving the flexible nature of the original substance.

On examining by reflected light, under the microscope, some pieces of chalk collected from the stratum which yielded the fossils above-described, minute particles of a brown colour may be observed scattered over the surface; these I have no doubt are remains of the integuments of foraminifera; for in one instance, three cells of the shell of a Rotalia lined with a similar substance, were exposed. Mutilated Rotaliæ, consisting of only four or five sacs (figs. 2, 3), and sometimes of but one (fig. 4), are common both in chalk and flint; and these invariably have a torn and collapsed appearance.

The fossil organisms termed by **Ehrenberg** *Xanthidia*, which have long been known in flint, and were formerly considered to be siliceous, have been shown by Mr. **Deane** to occur in the chalk in a similar condition to the Rotaliæ; an unequivocal proof of the flexible nature of the original (see fig. 1).

That the correctness of the statements embodied in the preceding remarks may be verified, I submit the specimens to the Royal Society for examination under the microscope.

I will only add, that if the explanation I have suggested of the facts described be correct, and the fossils before us are the delicate soft parts of animalcules preserved in chalk and flint, in like manner as the bodies of mollusks occur as a carbonaceous substance in the Wealden freshwater limestones—this discovery, though relating to some of the minutest forms of existence, may yet prove an important element in many of the most interesting speculations of the geologist; for in strata in which no vestiges of shells, corals, or other dense organisms have been detected, the relics of countless myriads of beings may lie concealed*.

Chester Square, Pimlico,
May 1846.

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* In confirmation of these views I may state, that Dr. **Bailey**, Professor of Chemistry in the United States Military Academy at West Point, whose high attainments as an accurate microscopical observer are well-known, had arrived at the same conclusions, from the examination of American specimens, before he was apprised of the result of my researches. In a recent communication, he informs me that he has obtained, from the marls of New Jersey, not only casts of the interior of the shells of *Rotaliæ* and *Textilariæ*, but also the soft bodies of the animals, in the condition of molluskite. I have detected similar specimens in marl from the same locality, sent to me by Dr. **Bailey**.

Description of the Plate.

PLATE XXI.

The specimens are represented as seen by transmitted light under the microscope, with the exception of figs. 13 and 15, which were viewed as opaque objects. The size of the originals is from about $\frac{1}{20}$th to $\frac{1}{200}$th of a line in linear dimensions; they are figured as seen by daylight; when viewed by the illumination of a lamp, they appear more transparent, and of a lighter colour.

Fig. 1. A Xanthidium from the grey chalk of Folkstone, presenting a torn and shrivelled appearance.

Figs. 2 and 3. Specimens of mutilated Rotaliæ from the Folkstone chalk.

Fig. 4. A single membranous empty sac of a Rotalia, very transparent.

Fig. 5. The soft parts of a Rotalia from chalk; the cells are distended with a dark substance.

a, a, a; globular bodies, probably *ova*.

Fig. 6. The usual appearance of the shells of Rotaliæ in chalk, when mounted in Canada balsam: the interior is filled with chalk, and presents no traces of the animal matter; numerous foramina are apparent. The shell of the specimen, fig. 10, was probably a larger individual of this species: from Dover.

Fig. 7. The body of a Rotalia uncoiled, the membranous sacs and their connecting tube being extended: from Folkstone chalk.

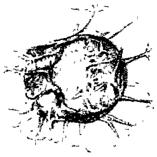
Fig. 8. A Rotalia in flint, with the internal parts preserved. All the chambers are occupied by the stomachs or digestive sacs, which are connected by the intestinal canal, and contain a brown granular substance.

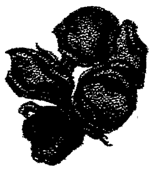
Fig. 9. The body of a Rotalia from the grey chalk of Folkstone, seen by transmitted light, and magnified 150 diameters. The shell and surrounding chalk have been removed by weak hydrochloric acid, and the specimen rendered translucent by immersion in Canada balsam; by Mr. Deane.

Fig. 10. The internal parts of a Rotalia from the chalk. The folds and duplicatures of the integument of the digestive organs are beautifully displayed; the intestinal canal is concealed by the membranous sacs; the discoidal arrangement of these organs is preserved in the inner convolutions. This specimen is in an extraordinary state of preservation: from Folkstone. The original is about $\frac{1}{20}$th of a line in diameter.

Fig. 11. Four large membranous sacs of a Rotalia seen in a fore-shortened position; the sacs are folded and collapsed. There are upwards of twenty *ova* (?) (*a, a, a,*) in connection with the anterior part of the specimen.

Fig. 12. A Rotalia in flint, with the soft parts remaining in the shell; the sacs

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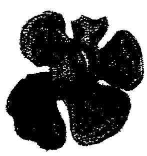
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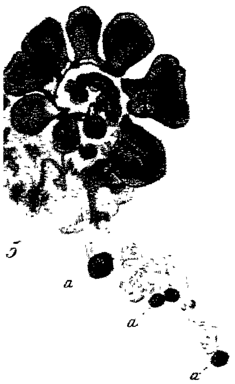
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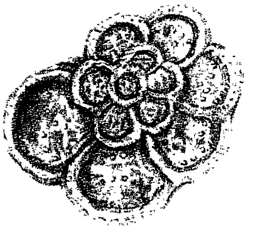
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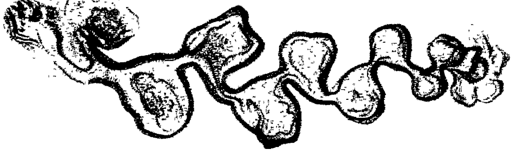
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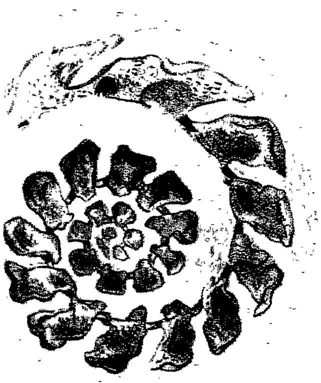
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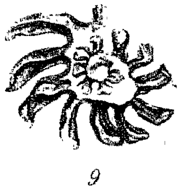
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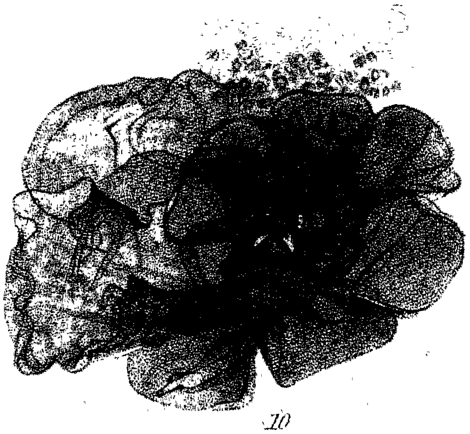
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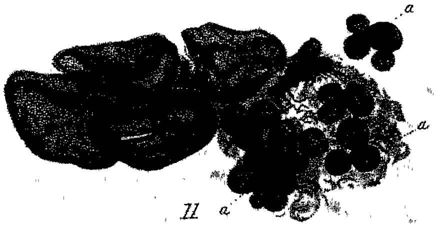
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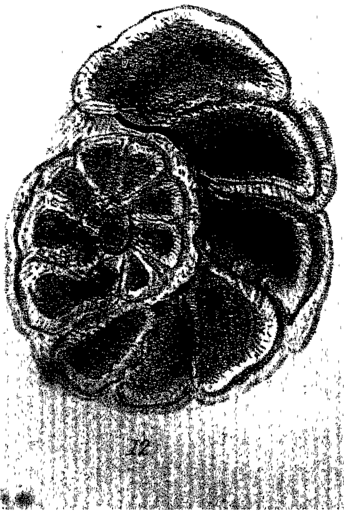
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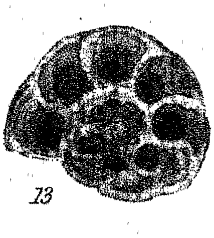
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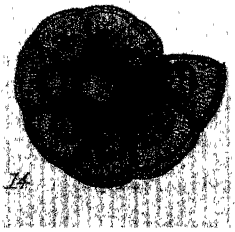
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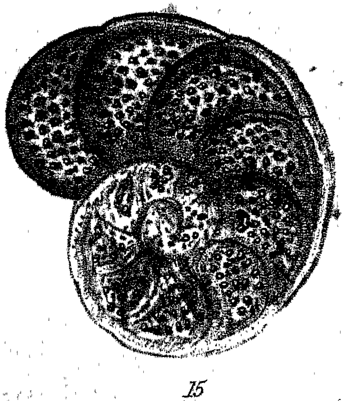
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and intestinal tube are partially filled with a brown granular endochrome, and are very distinct.

Fig. 13. A *Rotalia*, collected by Mr. WILLIAMSON, from a recent deposit of marine sand, near Boston, Lincolnshire. In this figure the specimen is represented as seen by reflected light, with a power magnifying fifty diameters.

Fig. 14. The same object viewed by transmitted light; the body of the animal occupies the chambers of the shell, as in the recent state, and closely resembles in appearance the fossils above delineated.

Fig. 15. The shell of a recent Rotalia from the Levant.

⁂ Figures 9, 13 and 14, have been added to the Plate, by permission, since the communication was read before the Royal Society.

XXIV. *On the Secretory Apparatus of the Liver.*

By C. Handfield Jones, *M.D. Communicated by Sir* Benjamin C. Brodie, *Bart.*

Received November 20, 1845,—Read February 5, 1846.

THE general arrangement of the structures composing the liver, especially of the vascular portion of the organ, has been well understood since the time when Mr. Kiernan's researches were published; the chief points which since then have engaged further inquiry, are the exact mode in which the minute biliary ducts take their origin, and the disposition and function of the epithelial cellular element, which physiologists now justly consider as an agent of primary importance in the elaboration of the biliary, as well as of every other secretion. Mr. Kiernan described the biliary ducts occupying the interlobular fissures, as anastomosing and giving off branches, which entering the tissue of the lobule, formed there a "reticulated plexus;" this account has been very recently confirmed by German anatomists of celebrity, viz. Muller, Weber, and Kronenberg, and their view is adopted and further confirmed by Mr. Paget in the last Report of the progress of Anatomy and Physiology, January 1845. Mr. Bowman's view of the arrangement is different; he denies the existence of any lobular biliary plexus, and states that the basement membrane terminates at the surface of the lobules; he confesses however that we possess no accurate account of the mode of termination of the biliary ducts, and seems to agree with Henle that it has not yet been determined in what manner the contents of the epithelial cells find their way into the ducts: these two points I hope to elucidate in some degree satisfactorily in the account which follows.

If a thin section of the liver be examined under moderate compression with a linear power of 70 to 100 diameter, a number of lobules are observed of an irregular form, which on the whole approaches the circular; in or near the centre of each of these is a large foramen indicating the position of the intralobular vein, the lining membrane of which can be clearly distinguished; from this to the circumference of the lobule, lines of dark or mottled appearance about $\frac{1}{1000}$th of an inch in width are seen radiating on every side; these radii can seldom be traced in a continuous line to the margin of the lobule, but either pass into others so as to form a long meshed network, or else dip down and become lost to view; those, however, which reach to the margin can often be followed for some distance towards the centre. The appearance now described is best observed in the liver of the Rabbit or the Sheep, but can be seen also more or less perfectly in the human liver, and in that of the common domestic animals. If in a broken lobule one of these radii be examined with a power of 200 linear, it is seen to be formed by the apposition of numerous epithelial cells in a linear series; these series are not constituted by a single file of cells, but they are to a certain extent superposed, so that one cell may be overlapped by one or more adjacent. No enveloping membrane can be discovered containing the lines of cells; they evidently lie free, side by side, in the interstices of the blood capillaries, and are surrounded and imbedded in a structureless substance of indistinct granular appearance, which probably constitutes their "blastema" or formative material. Each lobule is separated from the adjacent ones by narrow spaces, the interlobular fissures of Mr. Kiernan; and where three of these unite there is a triangular interval, the interlobular space. Now if the margin of an entire lobule be examined, it is found to be invested by a delicate membrane, through which the outline of the last epithelial cells of the several linear series may be clearly discerned; this corresponds to the basement membrane of Mr. Bowman; and the perfectly defined and smooth margin of a lobule invested by it, is strongly contrasted with the irregular jagged appearance of a broken edge. Traced laterally, this membrane is found to line the side of one lobule, to form the floor of the intervening duct, and then to ascend along the side of the opposite lobule, thus investing by a continuous surface the opposite sides of two adjacent lobules. Again, if we follow it along the margin of the lobule, we may often assure ourselves of its existence for one-half or more of the periphery; but it is rarely possible to trace it completely round, inasmuch as the plane of the section scarcely ever coincides perfectly with that of the duct; I have however in three or four instances *succeeded* in doing so; and in many others, where after tracing it along a great part of the circumference it has for a short distance been lost to view, I have obtained assurance of the presence of the duct by appearances of the following kinds, viz. the lighter colour and evident depression of the interlobular fissure, the existence of an opake deposit occupying the course of the duct, and which had been observed in other ducts whose cavities had been laid open; or lastly, by a dark line extending from one interlobular space to another, which was formed by the concurrence of the radiating linear series of two opposite lobules, which appear to meet and terminate above their common duct. But though the real arrangement be, as I have now described it, yet in by far the greater number of instances the lobules appear to be continuous with each other at one or more points, so that although at one level the outline of the lobule be well-defined by the zone of the portal vessel and the accompanying duct, yet in all others there is a continuity of tissue, both of the capillary and of the epithelial element; this view, which differs from that of Mr. Kiernan, seems to be admitted at present by most observers*.

It might be objected to the above description, which regards the lobules as embraced by interlobular ducts on every side, that those lobules which form the walls of portal canals must be without ducts on the side looking toward the canal, since

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[*] I have since ascertained that the livers of different animals vary in this respect; the lobules of the organ in the Pig are separated by fissures exactly in the manner Mr. Kiernan describes.

there exist no lobules there with which they can be in relation; the arrangement, however, appears to be quite in harmony with the description I have given. Those lobules which adjoin the portal canal on the side of the branch of the hepatic duct contained in it, have a collateral canal running along their sides from which interlobular ducts pass in at each corresponding fissure; the floor and sides of this canal are beset on their outer surface with epithelial cells; the remaining lobules, by far the greater number, which adjoin the branch of the portal vein, have a similar collateral canal from which interlobular ducts proceed, but it differs from the preceding one in not having a layer of cells on its outer surface; from both these canals branches pass off, which probably directly proceed to enter the main duct*.

The most important point in the foregoing description relates to the absence of real tubular ducts from the interior of the lobules, a view which, proposed some time ago by Mr. Bowman, has lately been contradicted by the German anatomists before mentioned, who in this respect coincide with Mr. Kiernan; I will therefore shortly state the proofs which appear to me satisfactory on this point. These are, first, the non-existence of basement membrane in the interior of the lobules, which in common with Mr. Bowman I have been unable to detect; yet were this simplest constituent of a duct present it could hardly escape notice, especially as in other glands it admits of being readily demonstrated; at the broken margin of a lobule it may be well seen that the projecting extremities of the linear series are quite free, and exhibit no trace of any containing membrane. Secondly, if the margin of a lobule be carefully examined, where it forms the side of a fissure, the basement membrane may often be clearly seen, and through its transparent texture the terminal cells of the linear series are easily distinguished, resting against and contained by it. Now were the membrane inflected to form lobular ducts, surely some indentation or irregularity would be visible at the margin of the lobule, but I have often traced the outline carefully without observing any such. A third proof is supplied by the result of some experiments which I made on rabbits. I tied the duct. com. choled., and shortly after death, which took place at periods varying from one to four days, I examined their livers: these organs were found to be beset on the surface and throughout their substance with numerous spots of deep yellow colour, evidently produced by accumulation of bile; a section of these spots, examined under the microscope, showed that they were very partial, never extending throughout the whole of a lobule, but frequently situated in two or more adjacent; their outline was always well-defined, and not the slightest appearance of a distended plexus of ducts could be observed: this last evidence appears to me conclusive. I can hardly conceive that if any plexus of anastomosing ducts existed, the accumulation of bile should take place in definite spots, and those not always situated in a single lobule, but in two or three adjacent. With regard to the proofs from injection which may be adduced in support of the contrary view, the suggestion of Mr. Bowman appears to me most probable, that the injection urged along the ducts had made its way into the interstices of the capillaries, and thus given rise to the appearance of a plexus; and in a subsequent part of this paper it will be shown that a condition of the lobules temporarily exists, in which such an occurrence might easily be conceived to take place.

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* The description above given has been taken from examination of the larger portal canals; with regard to the smaller ones I cannot speak so decidedly; but it seems fair to infer that the arrangement is similar.

Supposing it then conceded that the above account is correct, we may next inquire in what manner the structure described subserves the process of secretion as carried on in this organ. Now one peculiar circumstance at once arrests our attention, viz. that whereas in most other glands the epithelial cells are situated on the free surface of the basement membrane, and therefore in the cavity of the duct, they are here found on its deep or attached surface; in explanation of this it may be remarked, as Mr. Bowman observes, that the epithelial cells are, in point of function, the real continuations of the ducts, and the remarkable linear arrangement which so generally prevails, appears to me to suggest the idea that the rows of cells represent an intermediate stage of the development of primary duct tubules, the cells being apposed to each other, as in the formation of an ultimate nerve tube or muscular fibre. That the epithelium is the essential agent in the process of secretion, is now I think acknowledged by the great majority of those who have examined the subject. Mr. Goodsir, in his lately published work, has brought together a great number of examples, chiefly from the lower animals, in which it is distinctly shown that secretions of various kinds are formed during the growth of nucleated cells; and similar particles, especially under certain morbid conditions, may, in the very organ we are now examining, even in the human subject, be proved to fulfill the same office. Now where the epithelial cells are found on the free surface of the basement membrane, it is easy to conceive that the materials assimilated during their growth, are by the dehiscence of the cell, or its being cast off during the formation of fresh cells, set free in the cavity of the duct; but in the case of the liver the arrangement is very different, the greater proportion by far of the secreting cells being remote from any free surface on which their contained products might be poured out: the question then presents itself, in what manner does the secreted material of the cells find its way into the cavity of the surrounding duct? I will now detail the observations I have made which bear on this point.

The ductus communis choledochus of a rabbit was tied, death ensued in about twenty hours, apparently from gradual sinking, no traces of inflammation being visible; the gall-bladder was found tolerably full of healthy bile, the liver healthy, with the exception of some masses of morbid deposit which I have elsewhere described*; these were however quite local. On examining thin sections near the surface, where a good view of the lobules and their intervening ducts was obtained, it was manifest, in almost every instance, that accumulation of bile had taken place in the centre of the lobules, as indicated by a yellow zone of some width surrounding the intralobular vein; no other change from the usual appearance was observed. Now this case presents, I think, the earliest effect of interruption to the flow of the secretion, and the appearance noticed seems to point out the exact point where the secreting process has its first origin, viz. in the commencement of the rows of cells surrounding the central axis of the lobule; here, though in so remote a situation, bile is formed, and from hence it is doubtless transmitted.

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* Medical Gazette, October 24.

In many livers I have observed a remarkable difference between the condition of the peripheral cells adjoining the duct and those situated more centrally, while those in the interior appeared of their usual pale or light yellow colour; the terminal zone was of a much darker and more opake aspect; and often, where the cavity of the duct in the fissure was not exposed, its course was manifestly indicated by this dark tract, extending from one interlobular space to another; on more particular examination this dark aspect was found to depend on the presence of very numerous oil-globules in the cells which intercepted the light. Now as we find one or two minute oil-globules in almost every cell, the conclusion seems quite legitimate, that where these are found greatly multiplied, the cell which has produced them must be in a much more advanced state than those which contain but a few. In a human liver which appeared perfectly healthy I made an observation of similar import; the section had laid open the cavity of a duct for some distance, the margin of which on each side presented a perfect fringe of cells containing bile, while for a short space further on the course of the unopened duct was indicated by a yellow tract of cells extending above it, whose deep biliary tinge contrasted strongly with the pale tint of the surrounding substance; in several other ducts of the same liver a similar condition was observed. These observations render it nearly certain that the secreting process reaches its termination at the margin of the lobule, and I shall now endeavour to show in what manner the secretion is discharged into the cavity of the duct. The appearance which the margin of a lobule presents when the process of secretion has been proceeding actively, differs much from that which is observed when the lobule, so to speak, is quiescent; in the latter case, as I have described it, the margin is well-defined, and bounded by a distinct basement membrane, while the terminal cells of the linear series contain few and minute oil-globules, and do not appear to project outwards in any degree; in the other case the margin of the lobule has an opake cloudy appearance from the multitude of oil-globules; several cells are seen projecting into the cavity of the duct, giving the wall occasionally a tuberculated appearance; these cells contain oil-globules, and their wall is sometimes so extremely delicate as to be barely perceptible, even under a high power. Very many oil-globules are also seen, which lie evenly in contact with the sides and floor of the duct; it is difficult to determine whether these have escaped from their cells or not; it seems probable, however, that they are for the most part free, having recently been liberated by the solution of their cell-wall. The margin of a lobule in the condition now described presents no trace of basement membrane, the cells themselves form the wall of the ducts, preserving still the general outline; it seems therefore certain that the basement membrane is only a temporary structure, which disappears when the cells are actively discharging their contents. A forcible and instructive contrast to the above condition was exhibited by a liver which I examined, which was in an advanced stage of fatty degeneration; in this the linear arrangement of the cells was lost; they lay confusedly together, and were gorged with their fatty contents; the margin of the lobule, far from exhibiting any tendency to discharge the retained secretion, was invested, and, as it were, closely bound by a membrane, not of the delicate transparent texture of the basement tissue, but much more opake, and closely resembling the semi-fibrous aspect of thin layers of false membrane*. I may here observe that I have not been able to find any epithelium lining the interlobular ducts; the basement membrane, where it exists, appears quite bare, and through its transparent texture the terminal cells can be plainly discerned with their granular or oily contents; this is not in accordance with Mr. BOWMAN's opinion, who considers "the epithelium of the lobules to be continuous with that of the ducts;" from this however I am led, both by observation and the bearing of the facts now related, to dissent: it then becomes a question, in what manner does the epithelium of the larger ducts terminate? This is difficult to determine, but I am inclined to think that it serves only as a lining to those ducts which have no secreting parietes, and that in these it supplies the mucous secretion, with which we know they are lubricated. In the gall-bladder of a sheep examined immediately after death, the basement membrane of the plicæ was found to be beset with particles which had not the usual finely mottled aspect of columnar epithelium, but seemed to be composed of very minute globules; in a short time these dissolved away into an amorphous matter. In the hepatic duct the epithelial particles were very small, about $\frac{1}{7000}$th of an inch in diameter; these also disappeared very soon; the general surface was covered by a great number of globules considerably larger, but of very various size, which closely resembled the mucous globules in the secretion of the nose or pharynx. A similar appearance was observed in the hepatic duct of a dog, where after a very short time, the epithelial particles covering the surface became converted into groups of minute globules; according to this view, the *excretory* part of the duct would have its own peculiar protecting epithelium, preparing the surface for the passage of the bile furnished by the *secretory* portion†.

From all the facts which have been now related, it may, I think, be concluded, that the cells forming the margin of the lobule are those in which the elaboration of the secretion is perfected, and that as this is effected, they burst and discharge

* In cases of this kind the primary cell membrane is often seen to be manifestly altered, appearing striated and of a coarser texture.

† I have ascertained subsequently, by examination of perfectly recent specimens, that there is occasionally a layer of epithelium on the free surface of the basement membrane, but it is extremely delicate when it exists, is often absent, and does not appear to be in any way continuous with the secreting epithelium of the lobules.

their contents into the cavity of the duct; this view accords with that of M. Henle, as to the arrangement of the ultimate secreting elements of the mammary, lachrymal and salivary glands, which he believes to consist of vesicles filled with nucleated particles, seated on the closed extremity of a terminal branch of the duct.

It has now been shown that the secreting process commences in the centre of the lobule, and terminates at its margin along the line of the surrounding duct; but we have yet to consider the mode in which its progress is conducted, how the secreted material makes its way from cell to cell. This is a subject of which we have but little knowledge; the existence and nature of organic forces are as yet declared to us by their effects only; we can however refer to several examples, which exhibit a process similar to the one we are now considering; in cartilage, we believe the nutrition of the greater part of its substance to be performed by the nucleated cells which lie scattered throughout it, and attract from each other the nutrient fluid originally received from the blood; in the less perfect varieties of bone, crusta petrosa, the process is nearly the same. Mr. Goodsir, in his description of the human placenta, has stated that a double layer of cells is interposed between the maternal uterine sinuses and the umbilical capillaries of the fœtus, which are probably concerned in the transmission of fluids from one to the other; and lastly in plants, we know that there are several parts of their structure through which fluids are transmitted, which consist of nothing else but a congeries of cells. Some observations may now be mentioned which elucidate in some measure this function of transmission as performed in the liver. Having examined a considerable number of these organs, I have generally noticed that those which had been secreting most actively, which presented the least appearance of retained bile or oil, exhibited the linear arrangement of the cells most perfectly; while in cases of disease, where the secretion has been more or less retained or suppressed, the disposition of the cells has been much more irregular. It would therefore seem that the linear arrangement bears a relation to the integrity of the secreting process*. In examining isolated portions of rows of cells, where their outlines could be clearly distinguished, it has been very evident that they were differently disposed with regard to each other; some were seen to overlap the next in order, and the cell-wall could be clearly traced all round; others were flattened at their apposed edges, and simply united without overlapping; in others again the septum formed by their apposed walls was so indistinct that it could only just be discerned; and in a few instances it has appeared to be wholly or in part wanting, so that the cavities of the cells were fused together. Occasionally a globule of the secretion has been observed in the act of passing from one cell to the next, but in the greater number of instances there has not been any marked difference in the contents of cells constituting a linear series. Finally, I have several times noticed that the formation of young cells takes place chiefly at the extremities of the rows; I do not mean at the margin of the lobule, but in those which were seen projecting from a broken edge; in one instance a young cell had formed at the extremity of a row of four, it was distinguished by its smaller size, more distinct nucleus, and the absence of granular or oily contents; in front of it was a large and very distinct nucleus, with only a trace of cell-wall on one side. This would seem to indicate that the organic force which determines the formation as well as the growth of the cells is exerted chiefly in the longitudinal direction, *i. e.* in the axis of the row. The observations now related have an interesting correspondence with those recorded with respect to the behaviour of the cells at the margin of the lobule; in both instances the mature cell appears to dehisce in order to give exit to its elaborated contents; but in the one case this takes place into the cavity of the next cell; in the other, into the cavity of the surrounding duct. From all these observations, strengthened by the analogy to be mentioned, the following theory may perhaps be considered probable:—The mode of development of the Haversian canals in bone, of the primitive nerve tube and muscular fibre, presents us with examples of cells arranging themselves in linear series, very similar to those which we have described in the lobules of the liver; these cells thus arranged coalesce, and form the elementary parts of their respective tissues. In the liver the same type of arrangement seems to prevail; each linear series may be conceived to represent a primary duct tubule, the cavity of which remains divided by septa formed by the walls of contiguous cells; these septa at intervals give way, and by some unknown force (perhaps a *vis a tergo*, from accumulated secretion) the elaborated material is passed on to the next in order; a similar process being repeated in each cell of the series, till, by the dehiscence of the terminal one, the secretion is set free in the cavity of the duct.

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* In the case of a patient who died from the effects of dilatation of the heart, the liver was found to present the "nutmeg" appearance in a very marked manner, the cells mostly containing particles of bile of a bright yellow colour; their arrangement was remarkably plexiform, so as to give the appearance of a close network with small light interspaces.

APPENDIX.

The condition of the cells with regard to their coalescence is very various; in livers of sheep examined during the winter, a section, however thin, has been so opake that no satisfactory view could be obtained of it; in such the cells are found gorged with particles of secretion, and seldom, if at all, communicating; the basement membrane of the ducts has also a semi-fibrous aspect, and it is rare to observe the margin in an active condition. These facts, and the circumstance that the fusion of the cells is not so frequent in any case, as we should expect if it were essential, have led me subsequently to believe that a process of transmission *may* go on *through* the septa of the rows of cells and basement membrane, though there can be no doubt that it must proceed much more rapidly when the cells have coalesced and the basement membrane disappeared.

Fig. 1.

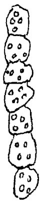


Fig. 2.

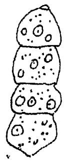


Fig. 3.

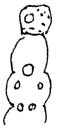


Fig. 4.

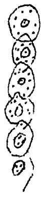


Fig. 5.

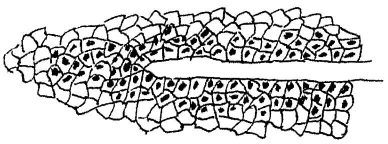


Fig. 6.

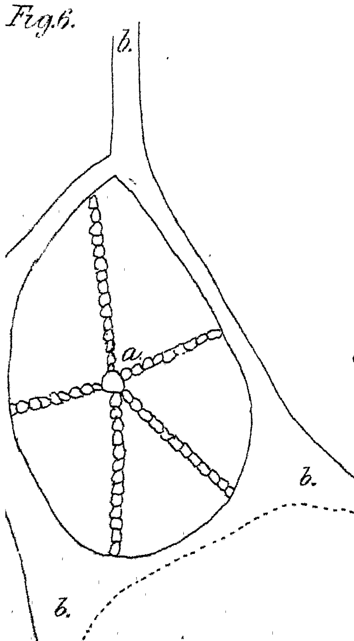


Fig. 7.

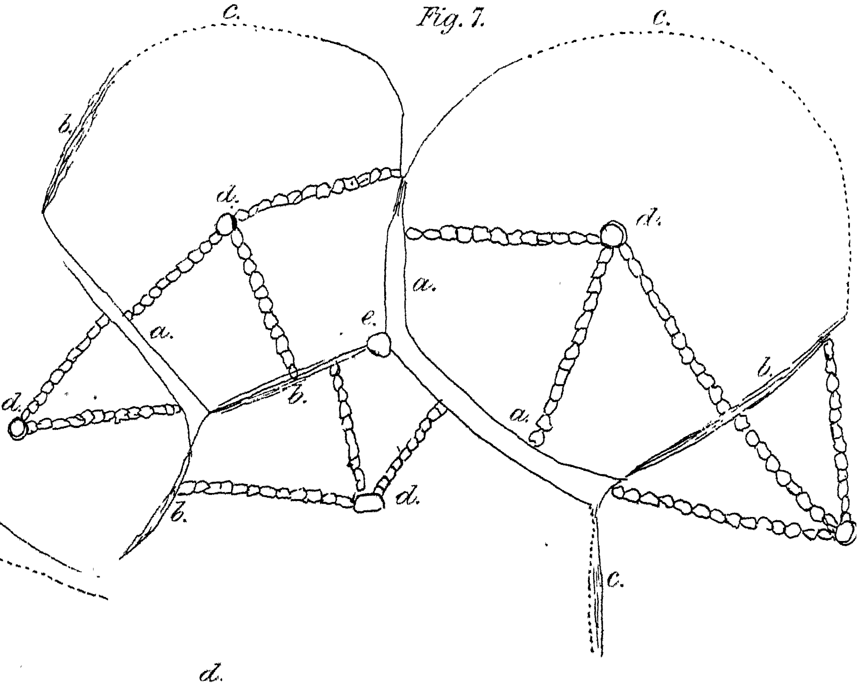
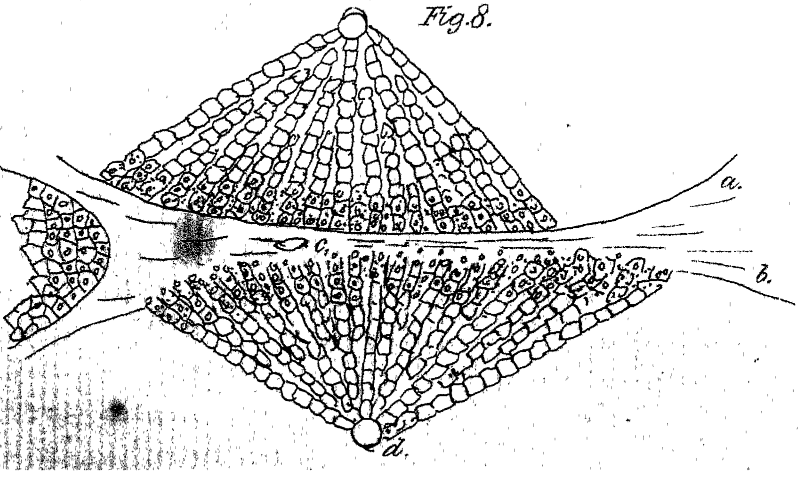


Fig. 8.



Explanation of the Plate.

PLATE XXII.

Fig. 1. Seven cells forming a linear series. None of them communicate with each other; they contain many oil-globules; no distinct nuclei. (From the liver of Sheep.)

Fig. 2. Four cells united together by their flattened and apposed margins.

Fig. 3. Three cells and part of a fourth. The septa between the 2nd and 3rd and between the 3rd and 4th have disappeared, and oil-globules are seen *in transitu*.

Fig. 4. Five cells of a linear series. The last is recently formed, as indicated by its smaller size and absence of granular contents; in front of it is a very large and distinct nucleus, round which a cell-wall has begun to form on one side.

Fig. 5. An interlobular duct partially exposed. Its margins are formed by cells containing bile, which also extend above it, in the direction of its course.

Fig. 6. View of a lobule completely surrounded by interlobular ducts. The basement membrane existed in each except where the dotted line is drawn. (From the Rabbit.)

a. Intralobular vein.
b.b.b. Interlobular ducts.

Fig. 7. Portions of five lobules, showing some interlobular ducts fairly exposed; the course of others is indicated by a dark tract of cells extending over them; in other parts adjacent lobules appear to blend with each other.

a.a.a. Interlobular ducts laid open by the section.
b.b.b.b. Interlobular ducts not laid open; a dark line indicates their course.
c.c.c. Margins of lobules indistinctly seen.
d.d.d.d. Intralobular veins cut across.
e. Branch of a portal vein cut across.

Fig. 8. The contiguous margins of three lobules, with the intervening ducts and the opening of an efferent trunk *c*.

a. Basement membrane distinctly seen limiting the dark peripheral tract of cells; secretion not proceeding.
b. No basement membrane existing; the extreme cells of the rows form the wall of the duct; the whole side of the lobule is covered with oil-globules which appear to be escaping from *open* cells.
c. An opening of communication with another duct; the basement membrane is seen lining the floor of the exposed duct, and is represented by fine striæ.
d. Sections of intralobular veins.

The above diagrams have been taken in all essential particulars from actual observation.

XXV. *Electro-Physiological Researches.—Fourth Memoir. The Physiological Action of the Electric Current. By Signor* CARLO MATTEUCCI, *Professor in the University of Pisa, &c. &c. Communicated by* MICHAEL FARADAY, *Esq., F.R.S., &c. &c.*

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IN my Treatise upon the Electro-Physiological Phenomena of Animals, at page 230 I have described the following experiment:—"I prepare a frog after the method adopted by GALVANI, separating the junction of the two thigh-bones, and placing them so divided between two glasses, with the claws immersed in these glasses. Introducing the conductors of a pile of from sixty to eighty pairs in both the glasses, I pass a current through the frog, which is direct in one limb and inverse in the other. After a lapse of from fifteen to twenty minutes, I establish a communication between the glasses by means of a wire, whereupon the limb traversed by the inverse current immediately contracts. On quickly removing the communicating wire, no contraction whatever occurs." I concluded from this experiment that the action of the electric current, in weakening or destroying the excitability of the nerve, was not the same whatever were its direction, and that the direct current acted with a much greater energy than the inverse. This fact appeared to me to be of sufficient importance to warrant further investigation, and I think that the results at which I have arrived will serve to throw some light upon that difficult subject, the physiological action of the electric current. I felt convinced, in the first place, that it now behoved me to employ means for the investigation of these phenomena far more exact than those I had hitherto resorted to. Every natural philosopher who has ever so little studied the contractions caused by the passage of the electric current upon the nerves of a frog, prepared for the purpose, must certainly have perceived how very difficult it is to arrive at satisfactory results, where the force of the contraction excited is to be judged of by the eye. In this manner our knowledge is limited to the fact, that when the excitability of the nerve is lessened, the direct current causes contractions only at the very moment in which it begins to circulate, whilst the inverse current produces contraction only at the moment of its ceasing to pass. In one word, we can only judge of these phenomena by their presence or by their cessation. But in what relation these effects vary, in what order, as regards intensity, the phenomena of the first period of excitability of the nerve are transformed into those of the second period; what relation the number of the contractions produced bears to the strength of the current, to its duration, &c., are so many questions which we shall never be able to solve without an apparatus by which to measure the contractions caused by the passage of the current. The apparatus which I have employed is that which Mons. Arago presented to the Académie Royale des Sciences, in the sitting of the 17th of September 1844, and the construction of which is due to the talent of Mons. Breguet. The apparatus principally consists of a solid brass support AB (fig. 1.) fixed upon a wooden stand, in which slide two pieces of metal C, D capable of being fixed in different places by means of screws of pressure (*vis de pression*). The piece of metal C is furnished with a vice E, in which is to be held the morsel of spinal marrow of the prepared frog, and is fastened there by three screws. The other piece F, of a forked shape, is provided with a hole in each extremity of the fork, in which a very fine wire G is fixed or regulated. At one end of the wire is a hook to which is affixed the claw of the frog, the other end of the wire is attached to a silken thread which winds round the little pulley I. Upon this pulley another thread of silk is wound, in contrary sense to the former, and to this is attached a small leaden weight O. The axis of the pulley is furnished with a kind of double index PQ, in the form of a semicircle. The axis is fixed upon two pivots, which admit of being

Fig. 1.

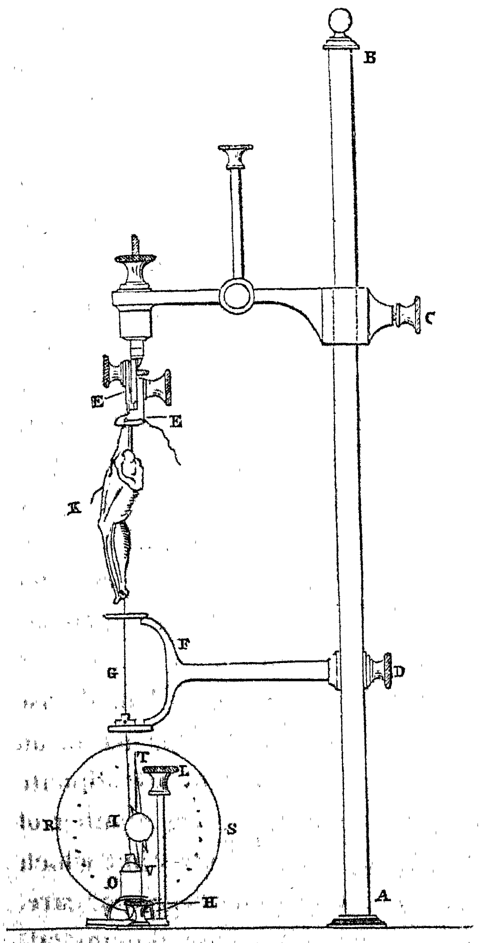


Fig. 2.

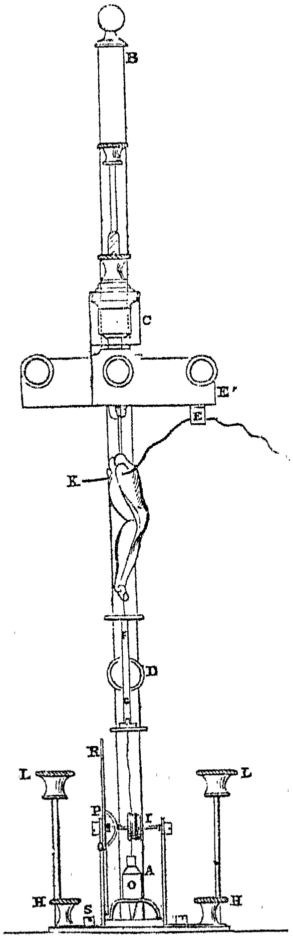
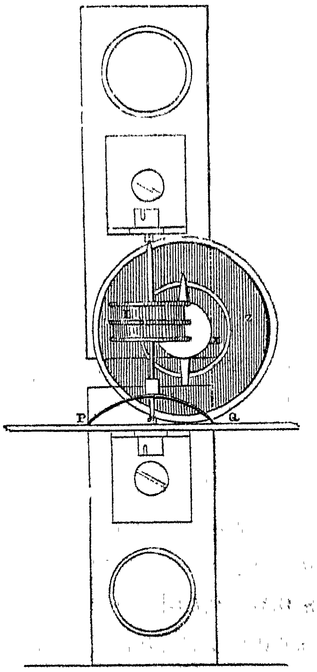


Fig. 3.



more or less approximated. One of these pivots is the centre of a circle RS, which bears a division. A long ivory needle TV is attached to this pivot; it is very light, and turns with the slightest possible touch. The use of this ivory index is obvious. In effect, when this index is brought in contact with the semicircular one PQ, which is attached to the axis of the pulley, and the pulley is put in motion, the movement is communicated tho te ivory index, and this latter will stop at the point at which it arrives in its gyration even when the pulley is brought back to its former position by the little weight. It must be allowed that without such an index as the one described, it would have been impossible to have judged of the extent of the movement of the pulley produced by the contraction, on account of its short duration. The weight I have been in the habit of using is 0·600 gramme, sufficient to allow of the limb returning to its position after the contractions have ceased; a heavier weight than this would stretch the nerve too much. The following is a description of the manner in which I pass the current. In every case it is always a half frog, deprived of the muscles and bones of the pelvis, which is used for this experiment. The half frog is thus reduced to a portion of spinal marrow, which is held in the vice, the nervous filament, the thigh and the leg, minus the claw, which is cut off. The little hook of the wire G is inserted between the bone and the tendo-achillis. Lastly, a gilded steel needle is thrust into the muscles of the thigh, as near as possible to the insertion of the nerve; and to this needle is soldered a very fine copper K covered over with silk, which is fixed to the piece of ivory E. It is quite clear that in order to pass the current through the nerve, nothing more is wanting than to touch the support AB with one pole of the pile, in any point whatever, and the wire which is soldered to the steel needle with the other pole. In all my experiments I made use of a Wheatstone pile, the elements of which, as everybody knows, are formed of an amalgam of zinc, contained in a cylinder of wood immersed in a solution of sulphate of copper in which the copper of the pile dips. I suppress here a great number of small details which are essential to complete success in the experiments, but which naturally present themselves to any person repeating them with some degree of care. One thing is very certain, which is, that it will ever be impossible to make any advance in the study of the physiological action of the electric current, without having recourse to processes which give the measure of that action.

The phenomenon which first engaged my attention is that which I had already observed, and which is referred to at the commencement of the present memoir. I have frequently repeated the experiment, varying the force of the current and the duration of its passage, and have found the results invariably the same. At the outset of the experiment, the two limbs, direct and inverse, are seen to contract both at the commencement and on the cessation of the current. After some minutes, varying from fifteen to twenty, according to the vigour of the animal, and especially according to the force of the current, the difference in the contraction of the two limbs manifests itself, that is to say, the leg traversed by the inverse current contracts only on breaking the circle, whilst the leg traversed by the direct current contracts only on closing it. The duration of the passage of the current, which is necessary for the production of these phenomena, is less in proportion as the current is stronger. If the passage of the current be continued through the same frog, it ends in the production of but one contraction, which is that which takes place on breaking the circuit, in the limb traversed by the inverse current. It is essential to the production of this latter phenomenon, to prolong the passage of the current more or less, from twenty to forty minutes, according to the strength of the current. I have frequently seen the contractions of the inverse limb prolonged, under the influence of a feeble current, and subsisting after four hours that the circuit had been kept closed.

I was anxious to ascertain whether these phenomena could be produced equally well by limiting the passage of the current to the lumbar nerves alone. In this view I wrapped very thin laminæ of tin round two nerves of the frog prepared in the manner above described, taking care to roll the laminæ round the nerves as close as possible to their points of entrance into the thighs. On passing the current, precisely the same phenomena as those already described are observable. The only difference that can be distinguished is in the duration of the passage of the current which is necessary for producing contraction only in the inverse limb, on breaking the circuit. This duration is less in this case than in the preceding experiments. This difference is easily accounted for, by taking into consideration the diminished resistance of the circuit in such a disposition, and comparing it with that of the circuit formed by the entire frog. Of this fact I have been enabled to satisfy myself completely, by introducing a galvanometer in the two circuits. The difference between the two currents, the same pile being used, is so great that it is impossible to entertain any doubt upon the subject. Since, then, the current is strongest when the nerve only is traversed, the phenomena corresponding to the different periods of excitability of the nerve ought to be obtained in a shorter time. I hardly need say that the manner of obtaining these phenomena, described at the commencement of this memoir, is identical with that which I have mentioned. In effect, the current in the frog may just as easily be checked or renewed by taking out and replacing the poles of the pile in the liquid in which the frog's paws dip, as by joining the two liquids by means of a metallic arc, and by removing the communication. Nevertheless it may not be useless to mention an experiment having reference to this, which it is as well to be acquainted with. I assume that the frog is prepared in the manner described, and subjected for a sufficient time to the passage of the current, so that contraction takes place only in the inverse limb, and on breaking the circuit. This being the case, while the circuit is closed, let a drop of pure water, or salt water, serum, blood, or any other conducting liquid, be dropped upon each of the two nerves separately. The drop produces no effect upon the nerve traversed by the direct current, while the contraction of the limb whose nerve is traversed by the inverse current s the immediate consequence of the contact of the liquid with this nerve. No such ffect follows the contact of oil or turpentine with the nerve. It is very evident that he conducting liquid bathing the nerve stops the current in the nerve itself, being a etter conductor. The contact of a muscular mass with the nerve produces the ame effect as a liquid conductor. All this proves that the conducting power of the erve is inferior to that of muscle and of distilled water.

I have repeated the above experiments upon living frogs. I prepared them in such a manner as to leave the two limbs united to the back by the lumbar nerves alone. I suspend this frog by hooks fixed to his lower jaw, and I pass the current from one paw to the other. I repeated the experiment frequently, and have always observed that after a certain time, varying from twenty-five to forty minutes, the inverse limb alone contracted on breaking the circuit. Thus it appears that it requires a somewhat longer time to produce the same effect with the electric current upon the nerve of the living animal, than upon the dead one.

It thus remains clearly proved that *the passage of the electric current through a mixed nerve modifies the excitability of this nerve in a very different manner, according to its direction: the nerve traversed by the direct current loses its excitability much more rapidly than that which is traversed by the inverse current.* I ought here to add, that hitherto we have no experiment proving that a nerve subjected to the passage of the inverse current loses its excitability otherwise than it would have done if merely left to itself. I return to the exposition of facts. Out of ten frogs submitted to the experiment above described, frequently eight at least present the following phenomenon:—On breaking the circuit after the current has circulated twenty-five or thirty minutes, the inverse limb alone contracts; but this contraction does not cease immediately after the circuit is broken. The inverse limb continues to be contracted, exhibits, that is to say, symptoms of *tetanus*. I have frequently witnessed the contractions lasting from ten to twenty seconds. If without waiting till the contractions cease the circuit is again closed, the limb, which was stiff and contracted, will be observed to give one more violent contraction when the circuit is in the act of being closed, and then immediately return to its natural state. It is not a rare occurrence to find frogs which present these phenomena after a lapse of three or four hours of experiment. These phenomena exhibit themselves equally when the passage of the current is confined to the nerve alone, to the exclusion of the muscle*. There is one observation which it is important to make with reference to the phenomena just alluded to. I have repeatedly stated that when the current has circulated for twenty-five or thirty minutes in the prepared frog, the only contraction is that of the inverse limb on opening the circuit. The circuit may be frequently broken and closed again, and there will be but that one contraction visible: there never will be any contraction either in the direct or in the inverse limb on closing the circuit. If the current be then passed for a certain time longer, on opening the circuit we shall have the persisting contraction already alluded to. On re-establishing the circuit during this tetanic condition, the inverse limb is convulsed for an instant, and then regains its natural state. This is the circumstance to which I wished to call attention: the contraction in the inverse limb on closing the circuit (which had previously ceased), *reappeared* when the phenomenon of the persisting contraction manifested itself.

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* This strong and enduring contraction which seizes the inverse limb upon breaking the circuit, offered me a favourable opportunity of witnessing the phenomenon of induced contraction. The nerve of the galvanoscopic frog should be stretched upon the muscles of the thigh of the inverse limb. On breaking the circuit the galvanoscopic frog becomes contracted, and *persists in this state as long as the inverse limb remains contracted.*

It is now time to speak of what happens if the nerves, after having been acted upon by an inverse current, circulating through them for some time, be then subjected to the influence of a direct current, or one taking an opposite direction. This case, which belongs naturally to the voltaic alternatives, is easy to foresee. The contraction subsists, but only at the moment of closing the circuit. As regards the limb which has been traversed by the direct current, on subjecting it to the inverse current, two things may occur equally easy to foresee. If the passage of the direct current through the nerve has been of long continuance, so that there is no contraction when the circle is closed, nothing takes place on passing the inverse current; there is no contraction on breaking the circuit. If, on the other hand, the passage of the direct current has not been too protracted, so as not to entirely destroy the excitability of the nerve, on passing the inverse current the contractions reappear on breaking the circuit. It will be seen in the course of this memoir, that it is clearly proved by experiments the most exact, that the contractions exhibited in this case increase within certain limits proportionally with the time of the passage of the inverse current. I shall reconsider these phenomena in the course of this paper, and at present limit myself to the conclusion that *the inverse current is not endowed with the property of destroying the excitability of the nerve; that in some cases it is clearly shown by experiment that this excitability is reproduced by the passage of that current, and that, on the contrary, the direct current easily destroys the excitability of the nerve.*

Lastly, I directed my experiments in the view of ascertaining the difference of excitability of the nerve due to the electric current according to its direction, by substituting the ordinary stimulating agents for provoking it, in the place of electricity. The following experiments admit of being easily verified. The frog is prepared in the usual manner, and is disposed for the experiment in the way so frequently described. The passage of the current is continued until there is no contraction except in the inverse limb on breaking the circuit. Arrived at this point, the passage of the current is to be interrupted, and each nerve is to be touched separately with caustic potassa, or better still with a heated iron; the result is so constantly the same that the direction of the current passed through the two nerves may even be told by it. The effect of the caustic potassa, or heated iron, upon the inverse nerves is merely that of producing contraction. The conclusions which we have drawn are very general: *the excitability of a nerve is modified by the electric current according to its direction*; and when we reflect that the passage of the inverse electric current through the nerve of an animal deprived of life, prolonged for two or three hours, produces on ceasing a very violent and persisting contraction, and that when this happens it has re-acquired the property, which it had lost before, of provoking contraction at the moment the inverse current begins to be passed, and that finally the passage of the direct current, for a time relatively very short, entirely destroys the excitability of the nerve, we are led to believe that *the action of the current upon the excitability of the nerve is opposite for opposite directions*. This is the point I wished to establish by experiments of measure, and I hope that I have satisfactorily demonstrated the fact. I began by measuring the contraction with BREGUET's apparatus, which I have described. It was important to determine and compare the contractions excited by the direct and by the inverse currents*, principally taking into account the duration of the passage of the current. In all these experiments the same nerve must never be submitted to the action of both the direct and the inverse currents. My mode of operating is this. I prepare the frog in the ordinary manner, and after having divided the pelvis from the rest of the trunk, I separate it into two parts, so that the two limbs remain united by the lumbar nerves attached to a portion of spinal marrow. I fix this piece of the spinal cord in the vice, and in this manner I am enabled to pass the current in either nerve *ad libitum*. By repeating a great number of experiments, sometimes beginning with the direct, at other times with the inverse current, it is not difficult to obtain a table of numbers which agree with one another as well as could be expected in this kind of experiment. I always leave the circuit open as short a time as possible between one experiment and another. A certain degree of practice enables the experimenter to employ only as short a time as two seconds in bringing the ivory index back into position. In the same way the shortest possible time for leaving the circuit closed is two seconds, for this is exactly the same time required for replacing the needle which had been removed from its position by the first contraction. The numbers which follow are the degrees of the division of the dial of the apparatus. It is unnecessary for me to give all the numbers resulting from my experiments; it will be sufficient to cite some of them in order to show the course of the phenomena. The following experiment proves the weakening of the excitability of the nerve owing to the passage of the direct current. Each passage of the current was prolonged for sixty seconds, and the following numbers give the measure of the contraction obtained each time the circuit was closed. These numbers are 16, 12, 10, 8, 4, 2, 2, 1. The inverse current was next tried on the other limb. On prolonging the passage of the current for two seconds I obtained a contraction of 10°. I left the circuit closed for sixty minutes, and still the contraction was 7 on opening the circuit. Thus far these numbers merely show the principal fact upon which I have insisted so strongly, which is, *the very different rate of reduction of the excitability observable in two nerves, one of which is exposed to the passage of the direct, the other to that of the inverse current.*

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* Both at the commencement of the current and on its ceasing.

It was very important to compare the excitability of a nerve subjected to the passage either of the direct or of the inverse current, with that of a nerve left to itself for an equal time. The results at which I invariably arrived are these: we are sure when employing the direct current that there will no longer be any contraction after the passage of the current has been kept up for fifteen or twenty minutes. With the inverse current, on the contrary, we have just seen that after a much longer passage of the current, the contraction produced on breaking the circuit was not greatly inferior to that which takes place in a nerve quite fresh, and having experienced the action of the current for only two seconds. The following are the numbers given by one nerve left untouched, and another exposed to the inverse current. I submitted to experiment a nerve left to itself; and twenty-five minutes after the preparation of the limb I passed the inverse current for the shortest possible time, and on opening the circuit the contraction was 20°. The other nerve, exposed to the current for twenty-five minutes without intermission, gave 18° on opening the circuit. In another experiment the numbers were 16° and 12° for a passage of thirty-five minutes. Repeating the same experiment with the direct current, I never remarked any perceptible contraction on breaking the circuit and reclosing it immediately. It is just to observe that the natural decrease of strength, independent of the passage of the current, ought to be greater for the nerve subjected to the experiment, and which is always somewhat stretched by the weight of the limb, than for the nerve which is left in a state of repose.

It is easy to prove that the passage of the inverse current in a nerve acts for a definite, though a very short time in producing an increase of excitability, which for the same reason disappears very quickly after breaking the circuit. To prove this I shall commence with an exposition of the experiments instituted for measuring the contraction produced, as well on closing as on breaking the circuit of the inverse current. We know, in general, what happens in this case. In the first place, when the nerve is very excitable, there is contraction both on closing and breaking the circuit, and little by little the former contraction disappears completely. The following numbers were obtained on leaving the circuit closed for two seconds, and open for that time. At first a contraction of 20° both on closing and on breaking the circuit; at the expiration of ten minutes there was no contraction on closing the circuit, but one of 12° on breaking the circuit. At the end of thirty minutes things were precisely the same. The following are the numbers obtained from another experiment under the same circumstances, but upon a nerve which had already lost much of its excitability.

Contraction on closing the circuit.	Contraction on breaking the circuit.
20°	20°
12	18
4	16
2	16
0	12
0	12
id.	12
	12
	12
	id.

When the nerve is very excitable the action of the inverse current may be proved to be proportional to the time of its passage, making the passage in one case excessively short. In effect, when the nerve is endowed with a very high degree of excitability, the contraction produced on breaking the inverse circuit, whether it be for one second, for twenty seconds, or even for thirty seconds, is always the same; but the case is no longer the same when the current is passed for a shorter time than one second. Unfortunately I have not been able to employ an apparatus for measuring the duration of the passage of a current for a shorter time than one second. The way I arrive at these results is this: instead of establishing the circuit by dipping one of the conducting wires of the pile in the same recipient of mercury in which is the other wire, I hold them both in my hands and bring them rapidly in contact with one another. The numbers obtained from various experiments and with different frogs are 22°, 24°, 28° of contraction, on breaking the inverse circuit, and these numbers were the same whether the current were passed for one second only, or as long as twenty seconds or thirty seconds. On touching one wire with the other very quickly, the contractions in the same circumstances were only 4°, 6°, 8°.

When instead of a nerve, the excitability of which is very great, we choose for our experiments one in which this is considerably diminished, it is easy to prove that the contraction produced by the inverse current ceasing to pass increases, within certain limits, proportionally to the time of the passage of the current. To bring the nerve to this state of excitability, it may be either left to itself for a long time, or be stimulated by frequent intermitted currents in rapid succession. Before detailing the results which follow, it is necessary to mention what happens when a nerve has been exposed for a long time to the passage of the direct current, or to repeated actions of this current in those cases in which the nerve is left to itself. In fact, in order to be able to measure what is due to the action of the inverse current, we must first know what is the effect upon the nerve of its being left to itself, after the direct current has ceased to act upon it.

Marianini had already found that a frog which has lost the faculty of contracting upon passing the current, re-acquires it on being left to itself for five seconds: I have studied these phenomena anew, measuring the contractions in a frog subjected for some minutes to the passage of the direct current: the contraction, which was 20° at the commencement of the experiment, was but 8° at its conclusion on closing the circuit, and 0° on breaking it. The interval of time that the circuit remained open was a little less than two seconds, that is to say, the shortest time for the experiment; in the same manner the circuit was left broken the shortest time possible. I next varied the time of the circuit remaining incomplete. The following are the results obtained: for two seconds of repose, 10°; for three seconds, 11°; for five seconds, 12°; for ten seconds, 12°. Where the nerve has lost still more of its excitability, the effect of the repose is protracted still longer. Upon a frog, the nerves of which had been traversed by the direct current during thirty minutes, 2° of contraction followed upon breaking the circuit and again closing it immediately. After two seconds of repose, the contraction was 6°; after three seconds, 6°; after fifteen seconds, 7°; after thirty seconds, 8°. The time, therefore—always very short—that the nerve is left unacted upon by the current, and in which it acquires all the excitability which it is capable of regaining, is so much the shorter as its excitability is greater. I must add, that the increase of excitability produced by the repose of a nerve which has been stimulated by the direct current, persists in this same nerve for a time admitting of being measured, even after it has been again subjected to the passage of the direct current. There were 2° of contraction on closing the direct circuit, which had already been closed for thirty minutes. Leaving the circuit open for fifteen seconds, then closing it, the contraction was 8°; then closing the circuit immediately, and leaving it closed as short a time as possible, I opened and again closed as quickly as possible, and the contraction was 6°. Proceeding in the same manner, and passing the direct current for four seconds, the contraction was 3°, for five seconds only 2°, as at the commencement. A very short time of repose is sufficient to restore to the nerve as much as it can regain of that excitability which it had lost by the passage of the direct current; in like manner a very short time of the passage of this current will dissipate the increase of excitability acquired by repose. In general, the duration of these actions is in the inverse ratio of the degree of excitability of the nerve.

We now pass on to those experiments which prove incontestably that *the excitability of the nerve is increased by the passage of the inverse current, and that, within certain limits, proportionally to the duration of the passage of this current.* After having arranged a frog in my apparatus, I pass a direct current through the lumbar nerve for thirty minutes; I then wait until all contraction from the passage of the direct current has ceased, and that even after having left the nerve in repose for thirty seconds or sixty seconds. I then pass the inverse current, which scarcely ever occasions any contraction on closing the circuit, but on leaving the circuit closed for a longer or shorter time, there are different degrees of contraction on breaking the circuit. The following are some of the numbers obtained. In one case, after passing the inverse current for two seconds, 4°; after five seconds, 6°; after thirty seconds, 10°; after 120 seconds, 10°. With another frog, which had been very long under the influence of the direct current, the contractions, after passing the inverse current for two seconds, 0°; after passing the current ten seconds, 0°; sixty seconds, 1°; 120 seconds, 2°. In another experiment, at the expiration of two seconds of the passage of the inverse current, contraction 0°; after a passage of five seconds, 3°; twenty seconds, 8°; fifteen seconds, 10°; thirty seconds, 10°. In a fourth experiment, the duration of the inverse current and the degrees of contraction were as follows:—two seconds, 0°; three seconds, 3°; ten seconds, 6°; fifteen seconds, 8°; thirty seconds, 10°; sixty seconds, 10°. In all these experiments I left as short an interval of time as possible between each such successive current.

It has been already seen what takes place when the inverse current is passed, and the nerve is endowed with a very high degree of excitability: the passage of the inverse current for only one second suffices, in such a case, to restore to the nerve all the excitability it is capable of acquiring. To distinguish the phenomenon we are now considering upon a nerve in the state of excitability alluded to above, the inverse current should be made to act for very small fractions of seconds.

Next in the order of our investigations, we are led to examine whether this augmented excitability of the nerve, produced by the passage of the inverse current, can persist, even after the cessation of this current, or whether, on the contrary, it can have no existence beyond the period that the nerve is under the immediate influence of the current. It has already been mentioned, that when the direct current has been made to act for twenty-five or thirty minutes, so as no longer to produce any contraction, on passing the inverse current there is scarcely ever any contraction on closing the circuit. This contraction, which is always the first to disappear, may still be reproduced, but to effect this it would be necessary that the passage of the inverse current should be prolonged considerably, and that the circuit should remain open as short a time as possible. In effect, every time that the frog presents the phenomenon of persistent and tetanic contraction, that is to say, after the inverse current has been passed for a considerable time, a contraction takes place on closing the circuit, and the tetanic convulsion ceases on the instant. It is therefore proved that this increase of excitability, produced by the passage of the inverse current, persists for a very short time when the nerve is very excitable, while this persistence increases with the diminution of the excitability, and with the duration of the inverse current. The same law is therefore always verified according to the different degree of excitability of the nerve.

A few experiments, conducted in a different manner, lead to the same conclusion. I pass an inverse current for some time through the nerve of a frog disposed in my apparatus; I then break the circuit, and leave it so for a time varying for each experiment. I close the circle, and always again break it immediately, and note down the contraction which follows. The circumstance which varies in all these experiments, is the longer or shorter repose given to the nerve which has previously been acted upon for a considerable time by the inverse current. In one of these experiments the contraction was 14° on opening the inverse circuit which had been long closed. Leaving the circuit incomplete for five seconds, and then completing it and breaking it again immediately afterwards, the contraction was only 4°. Again, I complete the circuit, and on breaking it, after the inverse current has been passed for ten seconds, the contraction again amounts to 14°. In another experiment it was also 14° on opening the inverse circuit, which had remained closed during 120 seconds. Opening the circuit, and after two seconds closing, then breaking it immediately afterwards, the contraction did not exceed 10°. Then closing again, and allowing the current to pass for sixty seconds, the contraction again became 14°, as in the beginning. Breaking the circuit again, and leaving the nerve in quiet for sixty seconds, I complete the circuit and open it again immediately, and the contraction does not exceed 8°. In another experiment, on opening the circuit after the nerve had been acted upon by the inverse current for sixty seconds, the contraction amounted to 18°. I then left the nerve in repose for five seconds, after which, closing the circuit and breaking it again immediately, the contraction was 12°. After twenty-five seconds of repose the contraction was 8°: finally, leaving the inverse circuit closed for five seconds, the contraction, on breaking the circuit, was again 18°, as at the commencement. It is therefore also proved by these as well as by all the former experiments, that *the increased excitability produced by the passage of the inverse current persists after the current has ceased for a time varying in length, according to the primitive excitability of the nerve*; if the excitability of the nerve is very great, the increase produced by the passage of the inverse current ceases immediately, or almost immediately, after breaking the circuit; while it persists longer if the excitability of the nerve is already weakened.

Up to this point we have only studied the action of the inverse current upon the mixed nerves of the prepared frog, so that the increase of excitability produced by the passage of the inverse current must necessarily be in some measure hindered by the weakening of this excitability, the consequence of death. It was therefore necessary to study the action of the inverse current upon a living animal. At page 200, and in the following pages of my Treatise on the Electro-Physiological Phenomena of Animals, I have described some experiments of this kind, which I have subsequently repeated. When a current from a pile, direct or inverse, is passed along the sciatic nerve of a live rabbit, it always occasions violent contractions of the lower limbs and of the entire trunk; the animal screeches and agitates itself. These phenomena present themselves equally with the direct and with the inverse current, both at the commencement and at the end; but a difference very soon appears if the circuit remains closed. With the direct current the contraction is soon over, and the leg alone contracts when the circuit is closed. With the inverse current the symptoms of pain remain when the circuit is closed, as also the contraction in the leg when the circuit is opened. The experiment may be prolonged for several hours with the same results.

The following experiments were performed for the purpose of comparing together the contractions caused by the direct and inverse currents at the instant of closing the circuit in both cases. The frog in these experiments was prepared in the manner described, then cut in half, and a nerve of one half was acted upon by the direct current, and a nerve of the other half by the inverse current. The experiments were repeated several times, first passing the direct current, at one time, through one half of the frog, and afterwards the inverse through the other half, or reversing this order. The following are the numbers obtained:—

Number of experiments.	Contraction on the introduction of the direct current.	Contraction on the introduction of the inverse current.
1	16°	8°
2	16	4
3	14	6
4	18	12
5	16	12
6	24	8
7	20	16
8	8	4

Although the correspondence between the numbers in the two columns is far from being constant, it is nevertheless proved in a very evident manner, that the contraction caused by the introduction of a direct current upon a mixed nerve, which has not been previously stimulated by the current, is always stronger than that which follows the introduction of the inverse current. The result is the same if a discharge of the Leyden jar is used to provoke the contraction; that is to say, a very slight shock from the Leyden jar, if direct, will cause contraction, and which would be insufficient to effect this if inverse.

While repeating the experiments referred to in the above table, I took occasion to note down the contractions which took place on opening the circuit of the inverse current. The contraction so produced is never stronger than that which occurs the first time that the direct current is passed. Both contractions are in general similar if the nerve is very excitable, and the inverse circuit left closed for a very short time. When the excitability of the nerve is considerably diminished, the inverse current must be made to circulate for a much longer time, to produce, on opening the circuit, the same contraction as that caused by the introduction of the direct current.

I will now sum up, with a few general conclusions, the results of all the experiments hitherto cited.

1. The passage of the electric current through a mixed nerve produces a variation in the excitability of the nerve, differing essentially in degree, according to the direction of the current through the nerve. This excitability is weakened and destroyed,

and that more or less rapidly, according to the intensity of the current, when it circulates through the nerve from the centre to the periphery (direct current). The excitability, on the contrary, is preserved and increased by the passage of the same current in a contrary direction, that is to say, from the periphery towards the centre (inverse current).

2. These variations in the excitability of the nerve, produced by the passage of the current, tend to disappear more or less rapidly on the current ceasing. If the nerve is taken from a living animal, or from one in which life is but just extinct, so that its excitability is very great, these variations only last as long as the current continues to pass; while they survive the cessation of the current by from one second to ten seconds or fifteen seconds, if the nerve has already lost some of its excitability.

3. If the same current be made to act upon a mixed nerve, the contraction which occurs on the first moment of its introduction is very different, according to its direction: the direct current always occasions a stronger contraction than that which is due to the inverse current.

In another memoir, which will be a continuation of the present, I propose to investigate, as far as is possible, the cause of this diversity of action of the current according to its direction in a nerve. The conclusions drawn above will, I hope, suffice for the present to form a much simpler theory of the physiological action of the electric current than that we have at present, if it be true that we have any at all.

All are aware that a spark is emitted on the instant the circuit of a pile is closed, and again on breaking the circuit. It is also well known that the spark emitted on breaking the circuit increases if the circuit is composed of an electro-magnetic spiral with its cylinder of iron. Let it be remembered that there is no sign of the current passing when the circuit continues closed; to produce contraction the circuit must be broken or closed anew. The simplest idea then which we can admit, and which is demonstrated by experiment, is that muscular contraction is excited in every case by the electric spark. That which might perhaps have appeared to be in opposition to the admission of this idea, is the fact of the frog contracting from very feeble currents. It is very easy to overthrow this difficulty. In fact, I may dispense with any further repetition of experiments by recalling VOLTA's opinion in support. Immediately after GALVANI's first discovery, VOLTA applied himself to the study of the action of the discharge of the jar upon the nerves of frogs and other animals; and in his very first memoir upon Animal Electricity, he declares that the prepared frog is without comparison the *most sensitive electrometer we possess*. In one of his experiments he found that a charge at all times sufficient to excite contractions could not be estimated at the $\frac{1}{20}$th of a degree of his straw electrometer. Indeed it is very easy to verify these assertions of VOLTA. My plan is as follows:—I take a small Leyden jar having about thirty square centimetres of coating, and after having charged it to saturation, I discharge it four times successively with a metallic rod, so as at last to produce no perceptible spark. In the same manner, at this point there is no sign given by the electrometer with a dry pile. I then place the prepared frog astride between the balls of the universal discharger, and establishing a communication between the coating of the jar and these two balls, very strong contractions of the frog follow. Continuing this operation in precisely the same manner, and producing successive discharges of the same bottle through the frog, I never obtain less than twelve contractions, and in some cases I have even had as many as twenty. The first fact which strikes our attention in these experiments is that which Volta himself did not fail to observe. The most feeble discharge, said Volta, directed from the nerve to the muscle, and which provokes contraction, is but the one-fourth or even the one-sixth of that which is necessary to produce contraction when directed from the muscle to the nerve. This difference we are enabled to measure more exactly by acting with the electric current. In order to repeat this experiment of Volta with greater facility, and at the same time in a more conclusive manner, I confined myself to making the discharge act upon the nerve alone in the following manner. The frog is prepared in the ordinary manner, the pelvis divided, and it is stretched upon an isolating plane; the two extremities of the universal discharger are so disposed as only to admit of the discharge circulating through the nerves and the portions of spinal marrow. Thus one nerve is traversed by the direct discharge and the other nerve by the inverse. I have always used the same bottle after having discharged it with the metallic arc. After the first contractions, which are excited equally in both limbs, that limb only continues to contract which is traversed by the direct discharge. These results occur equally when nerves, which have not previously been subjected to any discharge, are acted upon. This is easily put to the proof by merely discharging the bottle several times through other frogs before beginning to act upon those which had been purposely put aside without the shock being passed through them. It is soon seen, after a few touches, that that limb alone contracts the nerve of which was exposed to the action of the direct discharge.

We may therefore conclude that the action of electricity upon the mixed nerves of an animal living or recently killed, is reduced to the two following facts:—

1. The electric discharge traversing a nerve awakens muscular contraction; but this contraction is much stronger when produced by the direct discharge than when it is excited by the inverse discharge.

2. The electric current circulating through a nerve of a living animal, or an animal newly killed, produces a variation in the excitability of the nerve: if the current is direct, the excitability is diminished and destroyed; while, on the contrary, the excitability is preserved and increased by the passage of the inverse current.

It is needless to observe that these latter phænomena can be verified in the dead animal only within such limits as are necessarily fixed by the cessation of the vital conditions essential to the preservation of the properties of the nerve. It will be observed that I have not taken any account in this memoir of the sensations awakened by the passage of electricity in the nerve.

To complete this memoir, it only remains for me to show how the different phenomena, produced by the passage of the electric current through the nerve, may be arranged in groups founded upon the two principles quoted and deduced immediately from experiment. In this manner I hope to redeem my pledge of giving a theory of the physiological action of the electric current. It is only in this manner that the advance of the physical sciences can be promoted, by deducing, that is to say, the greatest number of facts possible from the smallest number of elementary facts. I do not indeed pretend to affirm that the two principles upon which I take my stand, and which are immediately deduced from experiment, are the simplest and most elementary facts in so vast a field as that of the connection between the electric and nervous phenomena; but it is certain that a great number of electro-physiological facts, which existed without any mutual relation, are now brought under the dependence of two fundamental facts. The manner in which a mixed nerve, subjected to the passage of the electric current, presents different phenomena according to the degree of its excitability, is this. In the first period of its excitability it is natural that the contraction should take place, whatever be the direction of the current in the nerve. On breaking and on closing the circuit, the electric discharge, which if the pile were strong enough would be accompanied by a spark, always takes place whatever be the direction of the current; consequently there ought to be contraction in every case. When the excitability of the nerve comes to be diminished, either by the passage of the current, according to the law which has been established, or naturally, the effects of the electric discharge can no longer be the same; when the direct current has been passed for some time there will be no contraction produced by the discharge which accompanies the breaking the circuit. By degrees, as the excitability becomes naturally enfeebled in the nerve, the contraction proceeding from the discharge, which takes place on closing the inverse circuit, will be found to disappear. From the excitability produced in the nerve by the passage of the inverse current, contraction will be produced by the discharge which accompanies the breaking of the inverse circuit. The alternatives of Volta may be explained in a like simple manner. A nerve, of which the excitability has been destroyed by the passage of the direct current, reacquires its lost excitability under the action of the inverse current; and it is thus that contraction should occur on breaking the inverse circuit, when there was no contraction on closing the direct circuit. According to the state of the nerve, the increase of excitability persists or subsides immediately after the passage of the inverse current. If the latter case occurs, there is never any contraction except on breaking the inverse circuit, while in the former case the contraction may likewise occur on closing the inverse circuit. It is invariably the case that the strongest of these two contractions is that which accompanies the breaking of the inverse circuit. It is scarcely necessary to say, that if the nerve has been previously traversed by the inverse current, before subjecting it to the passage of the direct current, the contraction in this case ought to be much stronger than that which took place before on opening the circuit. The unequal effect, according to the direction of the same discharge through a nerve, has been clearly demonstrated by experiment. Volta and Marianini have studied the voltaic alternatives by passing the current through muscular masses and along nerves, but without acting separately upon one nerve with the direct and another with the inverse current. Thus it happens, that in this way of operating, in the same muscular mass there are some nervous filaments traversed by the direct current, and others traversed by the inverse current. Starting from this principle, it is easy to refer the fine experiments of Volta and Marianini to the explanation which we have already given of the voltaic alternatives.

Pisa, March 22, 1846.

XXVI. *On the Mechanism of Respiration. By* FRANCIS SIBSON, *Esq. Communicated by* THOMAS BELL, *Esq., F.R.S., &c.*

Received December 18, 1845,—Read March 12, 1846.

1. SIX or seven years since, while examining the chest in persons subject to dyspnœa, I was struck by observing that the latissimus dorsi and the serratus magnus muscles acted during forcible expiration; on further inquiry, I found that neither of them acted during inspiration. I also ascertained that, on *inspiration,* the scaleni acted during the whole time; that the superior ribs came nearer to each other, and the inferior moved farther apart; and that the internal intercostal muscles between the six superior costal cartilages and the external intercostal muscles between the superior ribs were in action.

I communicated these observations to Professor BELL; he advised me to examine and figure the muscles of respiration in the lower animals. This I did.

After making an extensive series of dissections and illustrations of the respiratory apparatus in the animals that breathe with ribs, I exposed the muscles of respiration in the Dog and the Ass while alive, and observed what muscles acted on inspiration, and what on expiration. I afterwards inflated the lungs in the dead animal, and found that the same muscles that acted during inspiration were shortened when the lungs were distended. This was important, as it rendered the repetition of vivisections less necessary.

Having extended these inquiries to all classes of animals breathing by ribs, commencing with the simplest, and ascending to Man, I came to the conclusion that the mechanical part of the function of respiration was far more complicated than it has generally been regarded, and that in some important particulars the generally received opinions on the subject required to be essentially changed.

This series of researches form the subject of the following paper.

REPTILES, §§ 2–16.

2. The serpent tribe of reptiles, possessing no sternum, have ribs which are connected with the vertebræ only, being without costal cartilages.

SNAKE, §§ 3–11, Plate XXIII. fig. I. *a.b.*

3. In the Snake, the ribs, besides their respiratory action, serve as limbs for progression. The question, What are its respiratory muscles? becomes complicated with another question, What are its muscles of progression? Do the same muscles serve both functions, or is each function performed by distinct muscles?

Lateral muscles of locomotion (30).

It may be affirmed that the numerous many-headed lateral muscles (30.30.30.) which pass from rib to rib, are devoted to locomotion. They, acting on alternate sides, draw the ribs to which they are attached nearer to each other, curve the spine laterally, and spread the ribs of the opposite side farther apart. The other muscles probably serve both for locomotion and respiration.

4. *The ribs are simple.*

The ribs of the Snake are so simple that their action in breathing is very intelligible. If we distend the lungs to the full, and note how the position of the ribs is changed, what muscles are shortened and what lengthened, we shall ascertain what movements of the ribs will cause an inspiration, what an expiration, and we shall discover what muscles are inspiratory, what expiratory. The shortening of a muscle is conclusive evidence of its action; if we find one set of muscles shortened when we distend the lungs, another set lengthened, we know that the shortened muscles are inspiratory, the lengthened expiratory. I have not ascertained experimentally on the Snake that the same muscles act when the animal inspires that are shortened when we distend the lungs, but I have ascertained it in the Dog and the Ass. I observed these animals breathe when the muscles were exposed, noted the actions of the various muscles one by one, and after death inflated the lungs; those muscles that acted during inspiration were invariably shortened when the lung was distended, and those that were passive were lengthened; on the other hand, those muscles that were active during expiration, were shortened when the lungs were flaccid. This fact rendered it unnecessary to find out by further vivisections the actions of the respiratory muscles, they could be ascertained leisurely on the dead body and represented by accurate drawings; such drawings I have made by aid of the tracing-frame recommended to me by Dr. HODGKIN[*]. These drawings exhibit the changes effected in the form of the chest, the direction of the ribs, and the length of the various respiratory muscles in inspiration and expiration.

In the Snake all the ribs have similar motions and similar muscles by which the motions are effected.

5. On inspiration, or rather on distending the lungs, for I never noticed a snake inspire, the ribs are raised at their free extremity and throughout their whole course. The range of motion of the free end is greatest, that end being most remote from the centre of the ribs motion at the vertebræ. If we assume that the rib is a straight rod, we can examine the motions of the various ribs in relation to each other uncomplicated by disturbing or diagonal motions.

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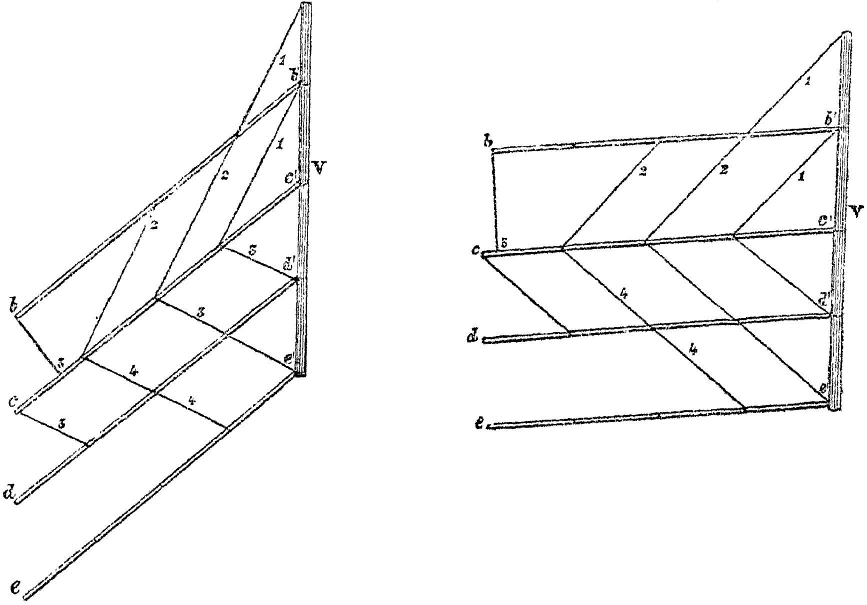
[*] This tracing-frame I have described in a paper on the Relative Situation of the Internal Organs, published in the volume for 1844 of the Transactions of the Provincial Medical and Surgical Association. It has been of essential value to me both in this inquiry and in that just referred to.

6. *On inspiration; the ribs are raised, move forwards, glide on each other, move farther apart. Diagrams* A 1.2.

Diagrams


A 1.
A 2.

In diagram A 1 the ribs are depressed at their free ends as in the state of *expiration.*

In diagram A 2 they are raised as in the state of *inspiration.*

V. indicates the spinal column.

b. c. d. e. the ribs, their free ends.

b'. c'. d'. e'. the vertebral ends of the ribs.

When the ribs are raised the free ends move forwards so as to be more distant from the vertebræ; the result is, the chest is deepened. The various ribs *b. c. d. e.* are more distant from each other in fig. A 1, inspiration, than in fig. A 2, expiration.

In fig. A 1, expiration, the free end of the rib *c* is considerably in front of a line *b*.3, drawn at right angles to the rib *b*. In fig. A 2, inspiration, the free end of *c* is very little in front of such line *b*.3; it follows that the lower edge of the superior rib *b* glides forward in relation to the upper edge of the inferior rib *c*; and *vice versâ*, the upper edge of the lower rib *c* glides backwards in relation to the lower edge of the upper rib *b*.

7. *The levatores costarum and external intercostals are inspiratory. Diagram* A 2.

It is evident that the line 1 representing the levator costæ is much shorter in diagram A 2, inspiration, than in diagram A 1, expiration; it is also evident that the lines 2.2.2 representing the external intercostals, which descend obliquely forwards, are much shorter in diagram 2, inspiration, than in diagram 1, expiration. It follows that the external intercostals are inspiratory.

The rib is raised by the levator costæ and by the external intercostal, and the upper edge of the lower rib is made to glide backwards in relation to the lower edge of the upper rib by the external intercostal, whose fibres, passing downwards and forwards, necessarily pull the lower rib upwards and backwards.

8. *The internal intercostals are expiratory. Diagram* A 1.

The line 3, representing the internal intercostal, whose fibres pass obliquely upwards and forwards, is much shorter in diagram A 1, expiration, than in diagram A 2, inspiration. It follows that this muscle is expiratory. The internal intercostal is expiratory, it lowers the upper rib, and causes its lower edge to glide backwards in relation to the upper edge of the lower rib.

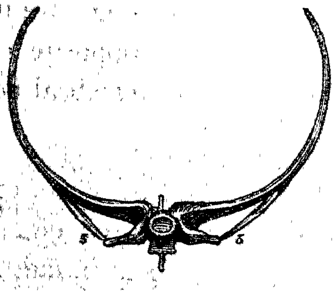
The line 4.4 represents a muscle in the Snake that passes over one rib to be inserted into the next rib but one above; it has the same action as the internal intercostals.

9. *On inspiration the ribs are drawn backwards posteriorly, outwards laterally, and move forwards anteriorly. Diagrams* B 1.2.

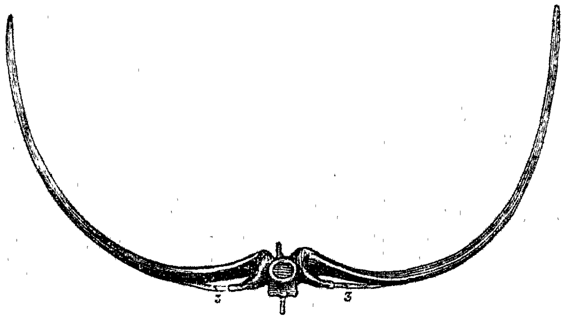
Besides the elevation of the rib during inspiration each rib is drawn backwards, so as to increase the area between the ribs of the two sides.

The levator costæ draws the rib backwards, B 2.

Diagram B 1.



B 2.



The ribs are drawn thus backwards by the levatores costarum, 3.3, the origin of which is behind the centre of motion of the rib at its articulation with the vertebra. The levator costæ (3) is shorter in diagram B 2, inspiration, than in diagram B 1, expiration.

The backward motion of the ribs during inspiration (B 2) counterbalances to a great extent the forward motion of their free ends, due to their inspiratory elevation, diagram A 2. § 6.

It follows that during inspiration the vertebral and lateral portions of the rib move backwards and outwards, while the free end moves forward; thus the space between the ribs is deepened and widened at the same time.

During expiration the ribs are lowered, their free ends move downwards, inwards and backwards; while the lateral and vertebral portions move downwards, inwards and forwards; thus the area between the ribs is narrowed and made less deep.

10. *Inspiratory muscles; scaleni* (fig. I. 1); *levatores costarum* (fig. I. 6); *external intercostals* (fig. I. 7); *&c.*

The inspiratory muscles in the Snake are the scaleni (1), descending from the cervical vertebræ to the first ribs, and by continuation to the succeeding ribs. The continuous fibres are parallel to and blended with those of the external intercostal muscles.

The external intercostal muscles (7) are shorter in fig. I. *e*, inspiration, than in fig. I. *d*, expiration. There are several other inspiratory muscles. Two of these (32.34) arise from the vertebra and are inserted into the rib, below and in front of the levator costæ, another (33) passes from rib to rib near the vertebræ; these are probably chiefly muscles of progression; they are all shortened when the lungs are expanded and the ribs are raised.

11. *Expiratory muscles; depressors of the ribs* (fig. I. 31); *internal intercostals* (fig. I. 21) (*pass within one rib*); *transversalis* (fig. I. 20).

The expiratory muscles.—A series of narrow, ribbon-like muscles (31), peculiar to the serpent tribe, lies in front of the vertebral portions of the ribs; each of these muscles takes its rise from the body of the vertebra, ascends obliquely outwards and passes in front of four or five ribs to be inserted into the lower edge of the fifth or sixth rib above. These muscles are attached about half-way between the vertebræ and the free ends of the ribs, and are much shortened when the lungs are flaccid. They pull the ribs downwards, and narrow the chest between the opposite ribs by drawing them nearer to each other, and by bringing forward their vertebral portion. They antagonize the levatores costarum.

A muscle (21) arises from the upper edge of the rib just above the insertion of the depressor of the rib, this passes obliquely upwards and outwards in front of one rib, to be inserted into the lower edge of the second rib above, near to its free end. This is shorter when the lung is flaccid than when it is distended, and is in fact a continuation of the depressor of the rib, the rib being interposed; it represents the internal intercostal.

A transversalis muscle (20) forms a musculo-tendinous web over the whole belly; it is attached to the inner surface of the rib where the depressor costæ is inserted, and acts with the depressor costæ to narrow the area between the opposed ribs.

There are cutaneous muscles that assist in expiration in front of the transversalis, which are connected with the ribs externally.

The Chameleon, §§ 12–16, Plate XXIII. fig. II.

12. The Chameleon, though a cold-blooded animal, whose movements are for the most part sluggish, and whose breathing is slow and irregular, yet stands in need of occasional very deep inspirations and very sudden and complete expirations.

13. *Has a sternum, and long costal cartilages in addition to the ribs.*

The Chameleon has a greater portion of rib movement than almost any other four-legged creature. The ribs, which are long and slender, yet strong, are eighteen in number; the lowest rib is at a very short distance from the pelvis. The first and second ribs have no cartilages; the rest, excepting the last, have long, firm, slender cartilages, attached by very flexible almost tendinous intermedia to the ends of the ribs. The costal cartilages of the third, fourth and fifth ribs, are attached to the sternum. They resemble closely the costo-sternal ribs of birds. The remainder have their anterior extremities free.

The addition of a complete system of anterior ribs or moveable cartilages gives the Chameleon a double power over the Snake for the expansion of its lungs. I defer considering the mode in which the anterior ribs act in expanding and narrowing the chest, until I describe the mechanism of breathing in birds, as it is so much more intelligible and explicable in the Bird than in the Chameleon.

14. *Inspiratory muscles acting on the ribs,* Plate XXIII. fig. II. 1.5.6.7.

The scalenus (1), the levatores costarum (5.6), and the external intercostals (7), have the same action and nearly the same anatomical distribution that they have in the Snake. They combine to elevate the ribs, push forwards their anterior ends, and draw backwards their posterior curves; they thus deepen and widen the chest. The fibres of the external intercostal muscles between the first and second, and second and third ribs, have the same direction with those of the scalenus, of which indeed they seem to be a continuation, the ribs being interposed.

In addition to these muscles, there is between some of the ribs another external intercostal (7), whose fibres are superficial to, and less oblique than the usual external intercostal.

15. *Inspiratory muscles of the cartilages,* Plate XXIII. fig. II. 9.

The first costal cartilage is raised by a strong triangular muscle arising from the sternum (9); strong muscular fibres pass from the first cartilage to the second, and raise it on inspiration; the rest have between them webs of aponeurotic tissue.

16. *Expiratory muscles,* Plate XXIII. fig. II. 31.21.32.30.19.17.

In expiration a series of small muscles (31) lower the ribs; each arises from the vertebra to be inserted into the lower edge of the rib above.

A set of muscles (21), as in the Snake, arise from the upper edge of one rib, and pass upwards over the inner surface of another, to be inserted into the rib but one above. An internal intercostal (21) arises from the upper edge of that portion of the rib into the lower edge of which the last muscle is inserted. This muscle is inserted into the anterior portion of the rib above. The Chameleon has peculiar to it a muscle to narrow the chest, by drawing the ribs inwards and nearer to those of the opposite side. This muscle (32) arises from the body of the vertebra anterior to the articulation of the rib, and is inserted into the inner surface of the rib near the vertebral head.

A long external depressor of the ribs (longissimus dorsi, 30) arises from the pelvis, and is inserted by many tendons into the lower edges of the ribs.

The chest is narrowed anteriorly by the transversales muscles (19.19) that arise from the anterior end of the vertebral ribs, and are inserted, the upper portion into the sternum, the rest into the costal cartilages; they cause the cartilages to bend on the ribs in expiration.

The ribs are lowered by an external oblique (17).

BIRDS, §§ 17–27 (Plate XXIV. fig. III. *a.b.c*, Plate XXV. figs. IV. V. VI. *a.b.*).

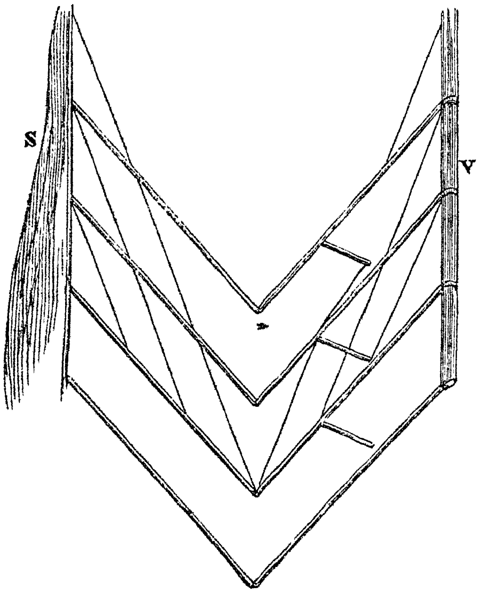
17. *Birds have, in addition to spinal ribs, a sternum and sternal ribs.*

Birds have a complete apparatus of ribs hinging on the sternum, in addition to, and articulated with, those hinging on the vertebral column. The vertebræ and the vertebral ribs combine with the sternum and the sternal ribs to complete a circuit, forming, as it were, a cylinder or cavity enclosing and protecting the lungs, heart, and abdominal viscera. In such a manner do they combine and articulate that, by the movements of the ribs, the cavity can be enlarged on inspiration and lessened on expiration. The sternum bears the same relation to the sternal ribs that the vertebral column does to the vertebral ribs. These sternal ribs are long slender bones that articulate at one extremity with the sternum, at the other with the vertebral ribs.

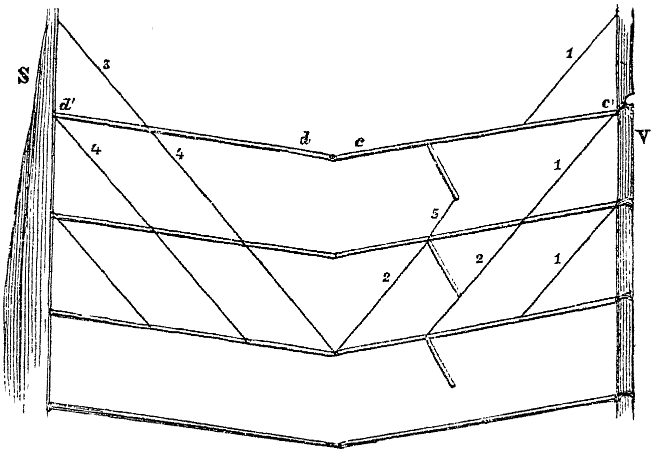
18. *Diagram* C 1.2. *On inspiration, the sternal as well as the spinal ribs are raised, glide on each other* (§ 6, 7) *and move farther apart.*

Diagram C 1 represents the vertebral and sternal ribs in the position they have in expiration; diagram C 2, that they take up in inspiration. It is here, as in diagram A 1.2, inferred that the ribs, both sternal and vertebral, are all straight rods of equal length, hinging on the vertebræ V and sternum S with upward and downward motions.

C 1.



C 2.



While the obliquity of the vertebral ribs is from behind forwards and downwards, that of the sternal ribs is from before backwards and downwards. The motions of the sternal ribs on the sternum are precisely the same in principle with the motions of the vertebral ribs on the vertebræ, only they are all reversed. While the distant ends of the latter ribs when raised move forwards from the vertebræ, those of the former move backwards from the sternum; while the upper edge of each vertebral rib glides backwards in relation to the lower edge of the rib above (§ 6, 7), that of the sternal rib glides forwards.

The same holds as to the muscles; while the scalenus or levator costæ (1) raises the vertebral rib, the sterno-costalis (3) elevates the first sternal rib; while the external intercostals (2) elevate and give the gliding motion to the vertebral ribs (§ 6, 7), the sternal intercostals (4) give the same motions to the sternal ribs; and while the muscles of the vertebral ribs are directed forwards and downwards, those of the sternal ribs pass backwards and downwards. The two sets of muscles combine in one action to raise the ends by which the two sets of ribs articulate with each other (§ 6, 7).

19. *On inspiration, the angles formed by the ribs are more open, the sternum and spinal column more distant.*

In diagram C 2, inspiration, the angle *d.c* formed by the articulation of the two ribs is much more open than in diagram C 1, expiration; in the latter they are bent to a right angle, in the former they are nearly straight. As the costal ends of the ribs are more distant from the sternum and vertebræ in inspiration C 2 than in expiration C 1, so, to a double extent, is the distance increased between the sternum and the spinal column; if the spinal column be fixed, the sternum moves forwards to a very great extent.

20. *Spinal ribs.*

All the spinal ribs, except the two first, which have free anterior extremities, articulate with sternal ribs. Those ribs that articulate with the vertebræ, and likewise with costal ribs, are of about equal length, and have spurs from their lower edges to give attachment and purchase to various muscles. The lowest ribs articulate with the pelvis. The pelvic ribs have no spurs, are longer than the purely vertebral ribs, and usually articulate with sternal ribs that are joined to each other near the sternum, with which they have a common articulation.

Each purely vertebral rib has two articulations, one with the body, the other with the transverse process of the vertebra; this last attachment allows the rib to be raised, but prevents that free range of forward motion that is permitted in the Snake.

21. *Sternal ribs.*

The superior sternal ribs are very short, many times shorter than the corresponding vertebral ribs; they become gradually longer, the lowest equalling in length the corresponding vertebral ribs.

22. I have watched the motions of the chest in the living fowl, and observed the action of a few of the muscles by vivisection. Figs. VI. *a.b.* Plate XXV. represents the Swan; in fig. VI. *a.* the chest is contracted; in fig. VI. *b.* expanded. I could not distend the lung owing to the air-sacs; but I imitated inspiration exactly by drawing the sternum further from the vertebræ. It will be seen from these diagrams that the elevation of the ribs pushes forward the lower part of the sternum much further from the spine than the upper. This is owing to the lower sternal ribs being much longer, and having therefore a much greater range of motion than the upper.

23. *Inspiratory muscles of the spinal ribs. Scalenus* (1), *levatores costarum* (2), *external intercostals* (7). Plates XXIV. XXV.

The scalenus (1) is prolonged from the first to the second rib; it corresponds exactly with the levatores costarum (2), which muscles both elevate the ribs and expand the chest. The inferior levators are smaller than the superior, the range of their action being more limited.

The external intercostals (7) are throughout shortened in fig. VI. *b.* inspiration. A portion of the muscle, with fibres almost horizontal, arises from the spur, and shows beautifully the mode in which the muscle acts to draw the upper edge of the lower rib backwards, in relation to the lower edge of the upper rib; in fig. VI. *b.* inspiration, the great shortening of these fibres is well seen.

24. *Inspiratory muscles of the sternal ribs; sterno-costal* (9 *a*); *sternal intercostals* (9).

The superior sternal ribs are raised by the sterno-costal muscle (fig. VI. 9 *a.*), which corresponds with the scalenus; it arises from the upper part of the sternum, and descends to be inserted into the upper edge of the four or five superior costal ribs; the bellies to the respective ribs lie behind each other in laminæ: this muscle is much shorter in fig. VI. *b*, inspiration, than in fig. VI. *a*, expiration, as is another muscle arising from the coracoid and inserted into the three first sternal ribs. The fibres of the sternal intercostal muscles (9) are much shorter in fig. VI. *b*, inspiration, than in fig. VI. *a*, expiration; they, with the sterno-costal muscle, elevate the sternal ribs and make them glide on each other. The combined actions of the scaleni, the levatores costarum, the sterno-costal muscle, the external intercostals, and the sternal intercostals raise the ribs, and push the sternum forwards, the vertebræ slightly backwards.

25. *Inspiratory muscles arising from the scapula,* Plate XXIV. fig. III. *a*. 31.32.29.

I observed the three scapular muscles (31. 32 and 29) to act during inspiration; 31 and 32 evidently raise the ribs, acting from the scapula; 29 acts from the ribs on the scapula to elevate it, thus lifting it away from the expanding chest.

26. *Expiratory muscles; internal oblique* (18); *external oblique* (17); *rectus* (16); *transversalis* (20); *internal intercostals* (21 *and* 19 *a*. figs. III. VI.).

The antagonist muscles to the dilators of the chest are numerous. The internal oblique (18) and the internal intercostal muscles (21), with a muscle (30) acting from the pelvis, combine to draw down the spinal ribs, and to cause the lower edges of the upper ribs to glide backwards on the upper edges of the lower ribs. The external oblique (17), inserted into the spurs, draws the spinal ribs downwards, brings them nearer the sternum, and increases the bend of the sternal on the spinal ribs. The rectus (16) pulls the sternum with the sternal ribs downwards; the transversalis (20) draws them backwards. In the Fowl the upper part of the sternum is drawn nearer the spine, and the three superior ribs are depressed (the third rib owing to its peculiar curve) by muscles (19 *a*.) stretching from the sternum to the ribs.

27. The lungs and the costal walls are more developed in the Stormy Petrel (fig. V.) than in any other bird I have figured; the Swan (fig. VI.) ranks next in costal development, then the Hawk (fig. IV.), and lowest of all the Fowl (fig. III.). The development of the lungs and of the costal mechanism evidently depends on the power to sustain flight, to swim, to dive, or to act energetically. The Fowl, which scarcely flies, requires comparatively little lung; its alimentary canal is protected by an enormous prolongation downwards of the sternum, a very trifling portion of which serves for the costal articulations.

MAMMALIA (*not including Man*), Plate XXVI. figs. VII. VIII., Plate XXVII. figs. IX. X., Plate XXVIII. figs. XI. XII.

28. The chest is expanded in the Mammalia, as in Birds, by the varying position of the ribs; the principle on which the lungs are dilated in the two classes is the same; but there are many important modifications.

29. The lungs in birds are imbedded in the spaces between the ribs; they only have a free surface invested with pleura anteriorly. The diaphragm in the Fowl forms with this free surface of the lung an enclosed cavity.

In Mammalia each lung is enclosed in a distinct pleural sac, the whole lung being free, save where the air-tubes and great vessels are attached. This cavity is completely closed above, protected by ribs, muscles and fasciæ. The first rib is more intimately connected than any other with the sternum; in the majority of animals it either directly articulates with that bone, or is united to it by a short firm cartilage. It is in the expansion in every direction of the upper part of the chest, and the great range of descent of the whole diaphragm, the progressive lengthening of the ribs, the arched and comparatively mobile spinal column, and the usually small, jointed sternum, that the mechanism of breathing in the Mammalia chiefly differs from that in Birds; for in Birds the upper part of the chest is not closed in, the diaphragm has but a limited range of motion, the spinal ribs are nearly of a length, the spinal column is stiff, and the sternum is in one large piece.

30. *The costal cartilages of Mammalia are analogous to the sternal ribs of Birds.*

In the Porpoise (Plate XXVI. fig. VII.) a series of bone-like stiff costal cartilages articulate by distinct joints with the sternum and the six superior vertebral ribs. The Sheep, the Cow (Plate XXVII. fig. IX.), and the Pig have costal cartilages that articulate by joints with the ribs and the sternum. These cartilages are every way analogous to the sternal ribs of Birds; they differ merely in this, they are made not of bone, but of cartilage.

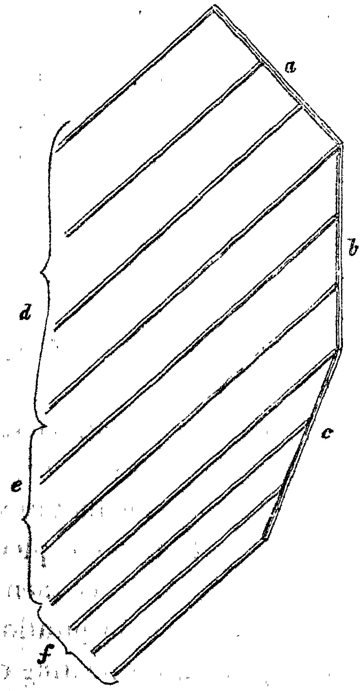
31. *Dorsal arch; the ribs are longest at the centre of the arch, and gradually shorten above and below.*

In all animals the lower part of the sternum is more distant from the vertebræ than the upper. The increase in length of the ribs and in depth of the chest takes place gradually from above downwards. The first rib is the shortest, the rest of the ribs increase gradually until about the sixth or seventh, which are the longest and are usually alike in length to each other and to the few following ribs; the three or four lower ribs gradually shorten, the lowest of them being the shortest. The dorsal vertebræ form an arch, the curves of which correspond with the varying length of the ribs. The superior curve of the dorsal vertebræ coincides with the gradual lengthening, and the inferior curve with the gradual shortening of the corresponding ribs.

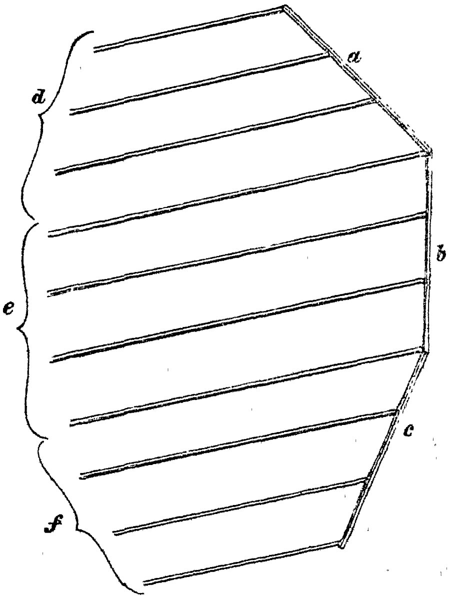
32. *Influence of the dorsal curves on the movements of the ribs. The upper ribs approach to, the lower recede from one another.*

The following diagrams (D 1, D 2) represent in an exaggerated mode, the curves in the dorsal spine, and the changes in position of the ribs when raised, as modified by the varying curve. *a, b, c* denotes the spinal column; *d, e, f* the ribs represented as straight rods; when the superior ribs *d*, articulating with the upper obliquity *a*, are raised as in D 2, inspiration, they approach each other. When those (*e*) hinging on the vertical portion of the spine are raised, they become more remote; and still more distant do those (*f*) become that articulate with the lower obliquity.

D 1. Expiration.



D 2. Inspiration.



This diagram is overdrawn and does not take into account the curved form of the ribs, their lateral thrust, the extent to which their vertebral portions are drawn backwards, the deepening of the dorsal arch, or the other causes that modify the results, but do not alter the principle demonstrated in the above figure.

We shall find this principle run through the whole of the Mammalia.

33. *Examples in the Ass, the Sheep, the Pig, and the Dog*, Plate XXVIII. fig. XI.*

In the Ass†, whose costal cartilages are unyielding and firmly united to the rib, the six superior ribs, which gradually lengthen, hinge from the upper curve of the dorsal arch; when they are raised, they all approach nearer to each other, the lowest of them, from its increased length, being more raised anteriorly than the rest. The seventh

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[*] Drawings are deposited in the Archives of the Royal Society, showing the position of the ribs and muscles, when the lungs are flaccid (expiration), and when they are distended (inspiration), in the Ass (fig. X. *a. b.*), the Pig (fig. VII. *a. b.*), the Sheep (fig. VIII. *a. b.*), the Dog (fig. XI. *c. d. e. f.*). These figures will be referred to in foot-notes.

[†] Fig. X. *a. b.* Archives of the Royal Society.

and eighth ribs are linked anteriorly to a common cartilage; their vertebral articulations occupy the hollow of the arch; when they are raised they retain their original distance. The six ribs below these have floating cartilages, hinge with the lower curve forward of the vertebræ, either immediately below or a little in front of each other, and they, when raised, become further apart.

In the Pig* and the Sheep†, whose short and firm costal cartilages articulate by joints both with the sternum and the ribs, the superior six (in the Sheep seven) ribs gradually lengthen; they hinge on the superior curve of the dorsal arch, and when raised they come nearer to each other; the two next ribs have united cartilages, and are neutral; while the lower ribs during inspiration become more remote.

In the Dog‡, whose costal cartilages are long and flexible, permitting free thoracic play, during inspiration the superior six ribs approach each other; the next two are neutral, and the remainder are more distant.

Man too partakes in this arrangement. Plate VII. figs. XIII. *a. b.*, XIV. *a. b.*, XV. *a. b.*

34. *Three sets of ribs. The superior, or thoracic; the inferior, or diaphragmatic; and the intermediate.*

The longest ribs which hinge on the hollow of the dorsal arch, and which neither approach to, nor recede from, each other during inspiration, form as it were a neutral ground between the superior ribs that approach to, and the inferior that recede from each other. The superior ribs, with their costal cartilages, form a complete circuit with the vertebræ and sternum to enclose the lungs and heart; it is their motion, increasing the area within them, that constitutes true thoracic inspiration; these form the thoracic set of ribs. The inferior ribs, each tipped with a floating cartilage, flank the abdomen on each side, have between them an open space in front, and give origin to the diaphragm; these form the diaphragmatic set of ribs. Their action is in aid of diaphragmatic respiration, their office being to enlarge the area of the chest simultaneously with the descent of the diaphragm, without which descent they would act, not on the lungs, which unless drawn down by the diaphragm are above them, but on the abdominal viscera, the more important of which it is their duty to protect. The intermediate set of ribs share duties with each of these sets, forming with the superior set thoracic, with the inferior, diaphragmatic ribs.

35. *The proportion of the thoracic to the diaphragmatic ribs depends on the proportion of the upper lobes of the lungs to the lower.*

The relative proportion that the sterno-vertebral ribs, or those of thoracic respiration, bear to those of diaphragmatic respiration, depends on the size and form of the upper lobes of the lungs, compared with the lower.

In the Ass, the upper lobes are small and narrow, the lower are large and full at their posterior part. The lungs are short in front at the sternum, long and broad behind and below. The superior (or anterior) part of the chest is narrow, the diaphragm is very oblique, the diaphragmatic ribs are numerous, and their expanding movements great.

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* Figs. VII. *a. b.* Archives of the Royal Society. † Fig. VIII. *a. b.* ibid. ‡ Fig. XI. *a.b.c.d.* ibid.

In the Dog, the body of the lungs and the upper lobes are large; they are nearly as long in front as behind. The base of the lung is horizontally concave; the diaphragm is drawn down almost as far in front as it is behind; the thoracic ribs are numerous, and have great play, at once deepening and widening the chest to a great extent. The diaphragmatic ribs are few in number.

§§ 36–54. Animals that have unyielding costal cartilages—the Pig, the Calf (Plate XXVII. fig. IX.), the Sheep and the Ass.

§§ 36–43. Costal Mechanism.

§§ 36–41. *Thoracic set of ribs.*

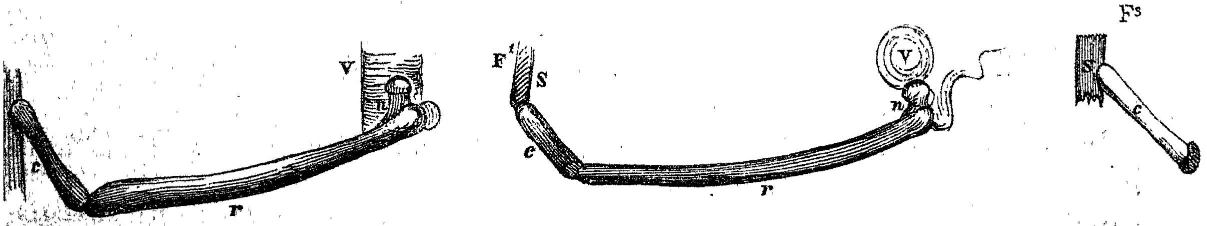
36. In the Pig* the straight costal cartilages articulate by moveable joints with the sternum and the sternal ribs. The seventh and eighth costal cartilages are linked together. During inspiration the six superior ribs are raised and drawn nearer to each other; the articulation with the cartilage is drawn slightly forward, and that with the vertebra backwards; the sternum is pushed forwards by the cartilages riding on the ribs. The superior curve of the dorsal arch is increased, the attachment of each of the ribs being further back in relation to that above in inspiration than in expiration. The extent to which the sternum and vertebræ are pushed further apart is inconsiderable; this is due to the great lateral expansion.

37. *The elevation of the ribs increases the depth and width of the chest. Diagrams* $E^{1\cdot 2}$, $F^{1\cdot 2\cdot 3\cdot 4}$.

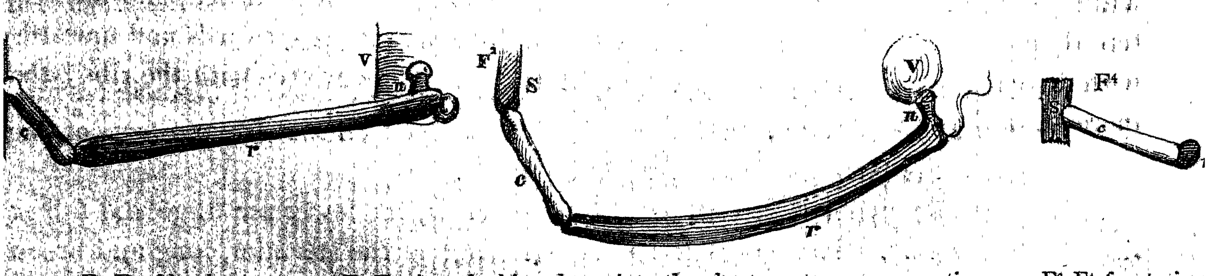
The diagrams E^1 and E^2 are side views, F^1 and F^2 views looking as it were down

Diagrams.

Expiration.



Inspiration.



E^1 E^2 side views. F^1 F^2 views looking down into the chest; a transverse section. F^3 F^4 front view into the chest, and F^3 and F^4 are front views of the rib of a Pig. E^2 shows the forward and backward thrust on inspiration, or increased distance between the sternum S and vertebræ V, and $F^{2\cdot 4}$, show the lateral thrust. The sternum S and vertebræ V not admitting of further separation, the raised costal cartilage acts like a crank on the end of the rib jointed to it, and pushes it outwards. The area of the chest between the opposite ribs is thus increased, and the elevation of the rib and cartilage is extended in two directions, one direction (E^2) to increase the depth, the other (F^2) the width of the chest.

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* Fig. VII. *a. b.* Archives of the Royal Society.

38. In the Pig, as we have seen, the elevation of the rib and cartilage is distributed in two directions, one direction forwards and backwards, the other outwards. The outward, or lateral thrust, is by far the greatest. There is in the Calf considerable forward movement of the sternum in addition to the lateral expansion. The lower costal cartilages are longer than the upper, consequently the lower part of the sternum is thrust further forward than the upper, exactly as it is in birds, and for the same reason (§ 22).

In the Sheep, when the lungs are distended, the vertebræ are, I believe, pushed slightly backwards, but nearly the whole of the force is expended in the lateral thrust; the chest, though but slightly deepened, is much widened.

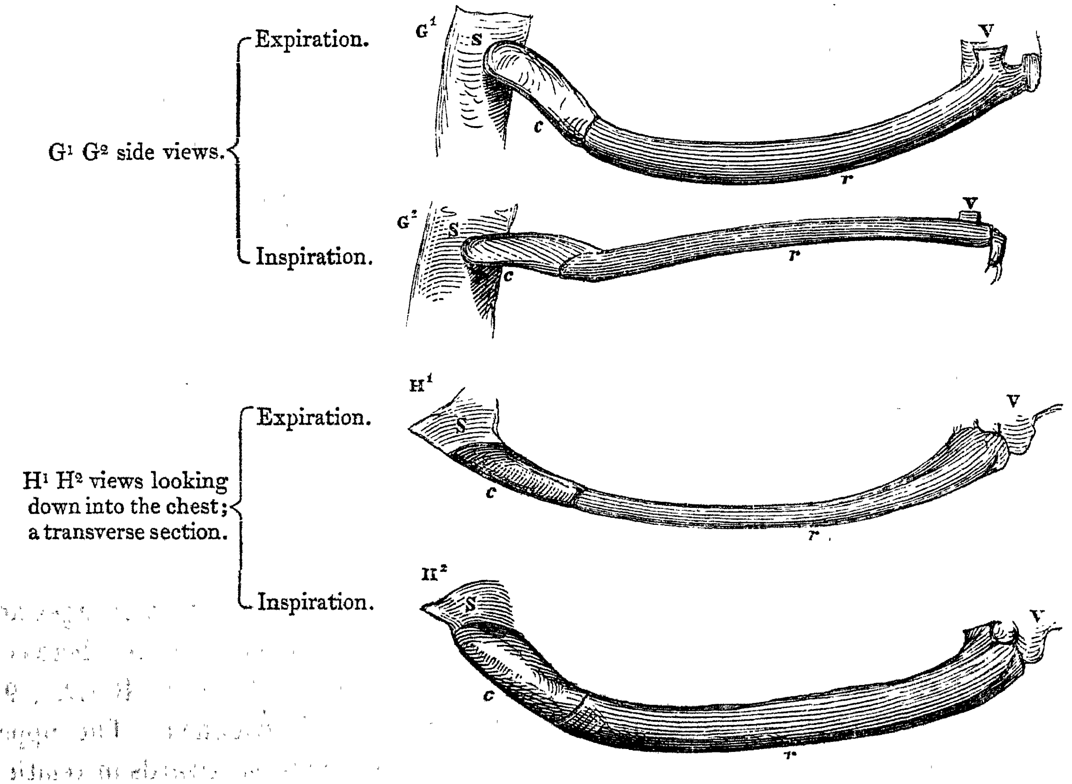
39. *Inspiratory changes in the position of the curves and surfaces of the ribs.*

The space between the ribs is further increased by the change in profile of the curves of the ribs. In expiration the upper edge (diagram E^1) and the inner surface of the rib (diagram F^1) are each slightly curved. In inspiration (diagram E^1), when the rib is raised, the curve of the inner surface is very greatly increased at the expense of that of the upper edge, the curve of which entirely disappears, giving place to a straight line; the form of the rib remains the same, but its profile and the direction of its surfaces are changed.

40. *Lateral expansion of the chest from the varying profile of the curves of the ribs in the Ass.*

In the Ass, the unyielding cartilage is firmly fixed to the rib so as to form one piece with it. The whole of the lateral thrust is due to the different direction of the costal curves. Nearly the whole of the respiratory movements go to increase the width of the chest. The sternal end of each cartilage is a little raised, and the vertebral end of the rib is slightly depressed; the sternum moves forwards and upwards with the cartilages; the spinal column backwards and downwards with the ribs; the increase in depth is very slight.

Diagrams.



Diagrams G^1 and G^2 represent side views, and H^1 and H^2 views as if looking downwards into the chest, of the rib of an Ass, as in expiration G^1, H^1, and inspiration G^2, H^2. The downward curve of the upper edge in expiration, G^1, becomes in G^2, inspiration, a slightly upward curve; G^1 presents a flat surface, G^2 a thin edge. In H^1, expiration, there is a slight curve on the inner surface; in H^2, inspiration, the curve is deepened; and the flat surface of the rib is presented instead of the edge, as in H^1. In fact that curve that looked upward in expiration G^1 looks inward in inspiration H^2, and the lateral surface in G^1, expiration, becomes in H^2, inspiration, the superior surface.

41. *On inspiration. The oblique internal surface of the superior ribs is more nearly horizontal. Diagram* I^1 I^2.

In the Pig, the Sheep, the Calf, and the Ass, the direction of the inner surface of the ribs is beautifully adapted to the lungs. The lungs gradually narrow from their body upwards to the summit; the interior of the chest forms as it were a dome at its upper part, to contain the upper lobes; the inner surface of the rib, which on expiration is nearly vertical, becomes on inspiration much more oblique. The dome of the chest is thus increased.

Diagram I^1. Expiration. Diagram I^2. Inspiration.

Section of the three superior ribs and their intercostal muscles (from the Ass).
I^1. Expiration. I^2. Inspiration.
1 *r*. First rib. 2 *r*. Second rib.
e. External intercostal. *i*. Internal intercostal.

42. *Diaphragmatic set of ribs.*

The posterior angles of the free or diaphragmatic set of ribs, whose cartilages are floating, are drawn considerably backwards. They thus increase the area between the opposite ribs in the manner demonstrated in the Snake (diagrams B 1.2. § 9). The space in front between the cartilages of the two sides is widened. The upper edge of each of these ribs, except the two or three lowest, glides backwards in relation to the lower edge of the rib above (§ 6. 7). The gliding motion that would result from the elevation of the two or three lower ribs (diagram A 1.2) is, I believe, quite neutralized by the greater degree to which the rib immediately above each of them is drawn backwards. Corresponding with the gliding movement of rib on rib, each cartilage glides downwards and backwards on that above it; each cartilage forms also a less acute angle with the rib.

43. *Intermediate set of ribs.*

The intermediate or neutral set of ribs (two in the Sheep and Pig, three in the Ass), whose cartilages united to each other articulate with the lower end of the sternum, neither approach to nor recede from each other during inspiration. The elevation of the superior rib acts to raise the rest. The bodies of the ribs move outwards, their posterior portion backwards, their cartilages slightly forwards, and the angle between the cartilages of the two sides below the sternum is enlarged. These intermediate ribs partake of the motions both of the ribs of thoracic respiration superior to them, and of the diaphragmatic ribs inferior to them. The distance between the lowest of the intermediate set of ribs and the highest of the diaphragmatic set is greatly increased on inspiration.

In the Ass, the lowest costal cartilages articulating with the sternum are so firm, that they form, with the set of three intermediate ribs, one unyielding piece.

§§ 44–54. Muscles acting on the Ribs.

44. The actions of the costal muscles are entirely subservient to the motions of the ribs. We cannot comprehend the actions of the muscles unless we rightly understand the movements of the ribs.

45. *In Birds and in Snakes all the external intercostals are inspiratory, and all the internal intercostals are expiratory.*

In birds, still more so in the Snake, the ribs are similar throughout and they all go through analogous motions. The snake has no sternum and sternal ribs; the bird has no set of diaphragmatic ribs with floating cartilages; all its lower vertebral ribs articulate with sternal ribs. All the external intercostals are inspiratory, all the internal expiratory (§§ 6–8).

46. *In Mammalia the superior intercostals have the opposite action to the inferior, because the superior and inferior ribs have opposite motions.*

When I exposed the muscles of the living and breathing Ass, I was surprised to find that while the superior external intercostal muscles were invariably inspiratory, the inferior were as invariably expiratory, and that while the posterior fibres of the same muscle were inspiratory, the anterior were expiratory. These were the facts; I could not gainsay them. It was only after much inquiry that they became intelligible, not until I had comprehended the varying movements of the ribs at different parts; then everything, step by step, became lucid.

The sole duty of the muscles is to move the ribs. It is not because two muscles, between two distinct pairs of ribs, have the same direction of fibres and the same name, that they perform the same functions; it is because the two sets of ribs go through the same motions simultaneously. If one set of ribs, the superior, approach each other, while the other, the inferior, go further apart, on each inspiration, ought we not, *à priori*, to infer that the two sets of muscles passing between the two sets of ribs will have different functions? that if the muscle between two superior ribs that approach each other be inspiratory, that between two inferior ribs that recede from one another will be expiratory? In truth we ought to infer this, for the fact is so. In fact it is not the system of muscles, but the system of ribs that we must regard.

47. *Scalenus.*

In the Pig, the Sheep and the Calf, in addition to the scalenus of the first rib, there is another scalenus that acts on a few of the superior ribs to raise them on their outer surface. The Ass possesses no scalenus save that of the first rib. This scalenus scarcely raises the first rib at either end, but it raises the rib at the centre, and converts the upward into an inward curve.

48. *Intercostal muscles of the thoracic set of ribs.*

By comparing the views of the Sheep, Pig, and Ass* in expiration with those of the same animals in inspiration (the lungs distended), we shall comprehend at a glance what muscles are shortened on inspiration, what on expiration; where the muscles are shortest in *a*, they are expiratory; where they are shortest in *b*, they are inspiratory.

During inspiration in the Sheep†, the first six external intercostals are shortened throughout. The superior ribs approach each other more than the inferior, the anterior third of each rib moves forward, the posterior two-thirds are drawn backwards, and the gliding motion of rib on rib is greater behind than before; hence the superior muscles shorten more than the inferior, the posterior fibres more than the anterior. The seventh intercostal space widens posteriorly; its muscle is shortened behind but lengthened in front, especially where it is inserted into the cartilage, which it bends on the rib in expiration.

During inspiration in the Ass‡, the six superior external intercostal muscles shorten, all save the anterior portion of the sixth, and the portions of the fourth and fifth inserted into the fifth and sixth costal cartilages. A great portion of the action of the external intercostals is spent in makng the oblique inner surface of the rib more horizontal. The fibres draw upwards the outer part of the rib, while the inner part is stationary, as diagram I^2. § 41 represents, and as is well seen in the third rib of the Ass. The gliding motion of the anterior portion of the ribs of the Ass is slightly reversed owing to each rib and cartilage forming one piece. The anterior half of the five superior conjoined ribs and cartilages moves forwards; the posterior half of those ribs backwards; the whole of the sixth, and to a greater extent, the inferior ribs, move backwards, though less in front than behind. The sixth, seventh, eighth and ninth cartilages either move forward or are stationary.

The whole of that portion of the internal intercostal between the cartilages shortens on inspiration, that part of the muscle having the same action on the cartilages that the external intercostal has on the ribs, raising and approximating them, and making them glide on each other. The fourth, fifth and sixth muscles between the ribs are throughout expiratory. During inspiration, the first, second and third ribs come so much nearer to each other in front that the tendency of the fibres to make the lower rib glide backwards is counterbalanced: about four-fifths of the first, one-third of the second, and a small portion of the third internal intercostal muscles between the ribs in their anterior portions are inspiratory; here the outer and inner layers of intercostals act at the same time by a mutual diagonal pull.

49. *Intercostal muscles of the diaphragmatic and neutral sets of ribs.*

The anterior fibres of the external intercostal muscles between the diaphragmatic set of ribs are lengthened, and the posterior fibres are shortened, during inspiration; the ribs move further apart, and are all drawn backwards through their whole extent, though more posteriorly than anteriorly; the two or three lowest ribs do not glide on each other. The lower external intercostals are almost entirely expiratory, as in them the gliding action and the separation of the ribs in some measure counterbalance each other, the fibres of the muscle being either expiratory or inspiratory, as the one action or the other overbalances. In the Sheep*, the three lowest muscles are divided into two portions, the anterior being expiratory, the posterior inspiratory.

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* Fig. VIII. *a.b*, VII. *a.b*, X. *a.b*. Archives of the Royal Society. † Fig. VIII. *a.b.* ibid. ‡ Fig. X. *a.b.* ibid.

The fibres of the external intercostals between the floating cartilages contract during inspiration, causing the upper edge of one cartilage to glide backwards on the lower edge of that above; we have thus a curious distribution of opposite functions in the same muscle, the anterior fibres, those between the cartilages, being inspiratory, the middle, between the fore-part of the ribs, expiratory, and the posterior, inspiratory. The whole of the internal intercostal muscles are expiratory, both those fibres inserted into the cartilages and those into the ribs. We have then a complete transposition of functions in many parts of these muscles; the external intercostals between the ribs being inspiratory above, expiratory below, those parts between the cartilages being expiratory above and inspiratory below.

The muscles between the neutral or intermediate set of ribs are almost neutral in action.

50. *Levatores costarum.*

The whole of the levatores costarum are inspiratory; they draw upwards and thrust outwards the angle of the rib, elevate the ribs behind and pull backwards the posterior part of the diaphragmatic (diagram B. § 9), the intermediate, and a portion of the thoracic sets of ribs. They assist the external intercostal in making the upper edge of one rib glide backwards on the rib above (§ 6. 7), and in so thrusting backwards the vertebræ with which the rib articulates.

§§ 51–54. CERTAIN MUSCULAR ACTIONS OF THE ASS OBSERVED ON VIVISECTION.

51. *In the Ass the fibres of the serratus magnus are expiratory above, inspiratory below, neutral in the centre.*

In the Ass, I observed, on vivisection, that during inspiration the two lower fibres of the serratus magnus were shortened, acting on the ribs of the intermediate set, which were drawn backwards in their whole extent; the origins at the scapula of the two lowest fasciculi of the serratus magnus are above the articulation with the vertebræ of the two ribs on which they act. The sixth fasciculus of the serratus to the sixth rib was neutral, neither expiratory nor inspiratory. That to the fifth shortened very slightly on expiration; all the superior fibres acting on the first, second, third and fourth ribs acted very decidedly to draw down those ribs on expiration. The articulations of these ribs with the vertebræ are considerably above the attachment of the serratus to the scapula; the centre of action of the serratus being considerably below the centre of motion of the ribs; the fibres fixed into those ribs act in relation to the ribs from below upwards and forwards to draw them downwards, and slightly backwards. We have here this curious fact, that the superior fibres of the same muscle, the serratus magnus, are expiratory, while the inferior fibres are inspiratory. The action of this muscle can only be demonstrated on the living body, but we might have inferred, *à priori*, on knowing the relative direction of the various fasciculi of the serratus and of the ribs into which they are respectively inserted, which fibres are expiratory and which inspiratory.

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* Fig. VIII. Archives of the Royal Society.

The serratus is in full stretch when the animal stands, and then it acts from the ribs on the base of the scapula: if all its fibres were expiratory, it is clear that when the scapular action is called into play, as the expiratory action would be constant, inspiration would be interfered with. If all were inspiratory, the expiratory action would be clogged. As it is, the central fibres which support the scapula are neutral, the superior expiratory, the inferior inspiratory, and by this beautiful adjustment every action of the muscle is unembarrassed.

52. *Serratus posticus superior.*

The whole of the eight fibres of the superior serratus posticus I found to act during inspiration.

53. *Serratus posticus inferior, superior fibres expiratory, inferior inspiratory.*

The four lower fibres of the serratus posticus inferior acted during inspiration to draw backwards the four inferior ribs, the two superior fibres of the same muscle acted, during expiration, on the eleventh and twelfth ribs to draw them downwards, while the fibres acting on the thirteenth and fourteenth ribs appeared to be neutral. The tendency of all the fasciculi of the inferior serratus would be from their direction to draw the ribs both downwards as in expiration, and backwards as in inspiration; the proportion in which the four lower ribs are drawn backwards overbalances that in which they are drawn downwards, and their fibres are inspiratory; but the proportion in which the eleventh and twelfth ribs are drawn downwards overbalances that in which they are drawn backwards, and their fibres are expiratory; as the downward and backward motions of the thirteenth and fourteenth ribs balance each other, the fibres acting on those ribs are neutral.

54. *Expiratory muscles.*

I observed the following muscles to act during expiration: the rectus abdominis, which draws down the sternum slightly, and the fibres inserted into the first rib arising from the tendon of the rectus; the external oblique, which pulls downwards and forwards the diaphragmatic ribs and a portion of the superior ribs; the inferior oblique, which draws down the lower ribs and their costal cartilages; the transversales, which draw nearer to each other the diaphragmatic ribs of the opposite sides, contracting the abdomen; and the sacro-lumbalis.

§§ 55-57. ANIMALS WITH FLEXIBLE CARTILAGES—THE DOG (Plate XXVII. fig. X.), THE SEAL (Plate XXVI. fig. VIII.), THE RABBIT (Plate XXVIII. fig. XI.), THE OTTER (Plate XXVIII. fig. XII.) and THE MONKEY.

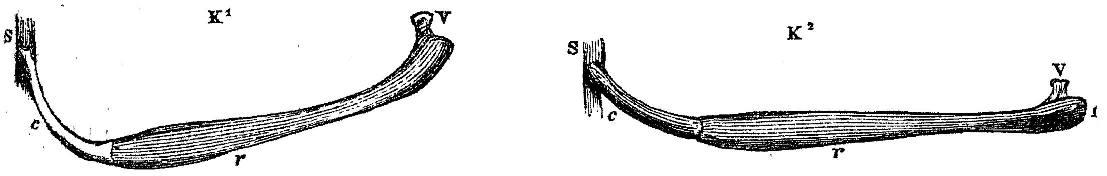
§§ 55-57. COSTAL MECHANISM.

55. *The Dog, Seal, Rabbit and Monkey.*—In the Dog and its allied species, the Seal and the Otter, and in the Rabbit and the Monkey, the costal cartilages are long, slender and flexibly elastic; they are firmly fixed to the ribs, and they articulate with the sternum. In the Dog and the Rabbit the articulation with the sternum is by a horizontal chisel-end that is united to it by a ligament, and moves freely upwards and downwards. In the Seal and the Monkey the articulation is between a ball-and-socket and a hinge-joint. The flexibility and elasticity of the cartilages permit them to bend and spring on themselves through their whole length. They have, in relation to the ribs and the sternum, exactly the same function and the same principles of action as the sternal ribs of birds, and the straight double-hinging costal cartilages of the Sheep, the Calf, and the Pig.

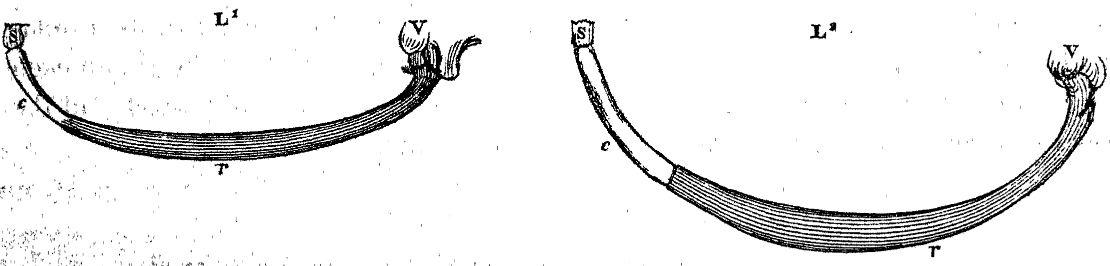
56. *The inspiratory elevation of the ribs increases the depth and width of the chest.*

Diagrams $K^{1 \cdot 2}$, $L^{1 \cdot 2 \cdot 3 \cdot 4}$ represent a rib in expiration $^{1 \cdot 3}$ and inspiration $^{2 \cdot 4}$. KK are side views; L^1 L^2 views looking down as it were into the chest, and $L^{3 \cdot 4}$ front views.

Diagrams.

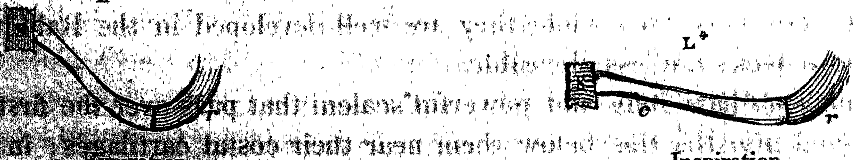


Side views.



Views looking down into the chest; a transverse section.

Front views.



Expiration. Inspiration.

In inspiration, diagram K^2, the rib and the costal cartilage are each raised, the elevation is, as in the Pig (diagrams EF, § 37), distributed in two directions. In one direction (K^2), the vertebræ are thrust backwards by the rib, and the sternum forwards by the cartilage, the chest being deepened; in the other direction (L^2 L^4), the outer portion of the rib and cartilage is thrust outward, the posterior portion of the rib is drawn backwards, and the anterior portion of the cartilage thrust forward. The greater and more extensive the play of breathing the longer are the costal cartilages, as we see in the Seal (fig. VIII.), and to a less degree in the Otter (fig. XII.). Both of these animals require very great play of respiration and unusual power to expel and renew the air at each respiration, owing to their diving habits. In the Dog, the Otter, the Rabbit and the Monkey, the first costal cartilage is stiff, and is firmly impacted in the sternum; in the Seal, the first rib is long and flexible, and hinges moveably on the sternum. During inspiration in the Dog* all the ribs are drawn backwards, the superior ribs to a less extent than the inferior: the first, second and third ribs are stationary at the anterior extremity, but all the rest move backwards through their whole extent, though more posteriorly than anteriorly.

57. *The thoracic and diaphragmatic sets of ribs**.

The upper edge of each rib glides backwards in relation to the lower edge of that above, and at the same time the upper edges of those costal cartilages that hinge on the sternum have a reverse direction, and glide forwards and inwards in relation to the lower edges of the respective cartilages above. The superior ten cartilages articulate moveably with the sternum, the tenth imperfectly. The ten superior ribs act as ribs of thoracic expansion; as the diaphragm ascends behind the sternum some distance into the chest the three lowest of them act with the eleventh, twelfth and thirteenth, or diaphragmatic set of ribs, to expand the chest when the diaphragm descends (see §§ 34. 35).

The floating cartilages of the three lowest ribs glide in the same direction as the ribs on which they ride; the upper edge of each cartilage sliding backwards in relation to the lower edge of the cartilage above. The six superior ribs approach each other, especially anteriorly; the seventh, eighth and ninth, are about neutral; all the lower ribs recede from each other.

58–69. MUSCLES ACTING ON THE RIBS.

58. *The scaleni of the superior five or six ribs are much developed.*

The scaleni are very greatly developed in all those animals with flexible cartilages. The scaleni of the first rib are very insignificant in the Seal and Otter, whose cervical vertebræ are very moveable; while they are well-developed in the Rabbit and the Monkey, whose necks are less moveable.

These animals all have long and powerful scaleni that pass over the first two ribs and are inserted into the ribs below them near their costal cartilages; in the Dog their insertion extends to the eighth; in the Otter and Monkey to the sixth; and in the Seal and Rabbit to the fifth ribs. The scaleni act during the whole time of inspiration to pull upwards the ribs into which they are inserted.

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* Fig. XI. *c.d.e.f.* Archives of the Royal Society.

59. *Sterno-mastoid, &c.*

The sterno-mastoid, sterno-hyoid and thyroid muscles, when they act from above, raise the sternum; when the sterno-hyoid and thyroid so act, their origins are fixed by the genio-, and stylo-hyoid and the hyo-thyroid.

60. *External intercostal muscles.*

The actions of the external and internal intercostals are in principle the same as those of the Ass and Sheep, varying as the ribs' movements vary (see §§ 46. 48. 49).

The first seven external intercostal muscles, where they pass from rib to rib, are inspiratory; the eighth (perhaps the ninth) are neutral anteriorly, and are inspiratory posteriorly.

The fibres from the third, fourth and fifth ribs inserted into the costal cartilages are neutral, but those inserted into the seventh, eighth, ninth and tenth cartilages, which in the latter pass from cartilage to cartilage, are all strongly expiratory; they bend the cartilage on the rib, and cause the upper edge of the lower cartilage to glide forwards in relation to the lower edge of the upper; movements the reverse of inspiratory. The three lowest external intercostals are inspiratory posteriorly, expiratory in the middle, where they act on the anterior portion of the ribs, and inspiratory anteriorly, where they pass from cartilage to cartilage; the anterior fibres cause the cartilage they are inserted into to slide downwards, outwards and backwards in relation to the cartilage from which they rise.

61. *Internal intercostal muscles.*

The first internal intercostal between the rib is inspiratory on its anterior four-fifths, the second and third in their anterior half and third; posteriorly they are expiratory; all the lower muscles between the ribs are expiratory; the expiratory action being less extensive in the superior than the inferior ribs, and in their anterior than their posterior portion. The fibres inserted into the ten superior cartilages are inspiratory, having the same relation to these cartilages that the external intercostals have to the ribs they are fixed to.

The internal intercostals between the three? lowest cartilages are expiratory.

62. *Elevator of the first costal cartilage in the Seal,* Plate XXVI. fig. VIII. 10 *a.*

In the Seal, whose flexible first costal cartilage hinges on the sternum, a muscle arises from the sternum and is inserted into the first cartilage that is analogous with the internal intercostal fibres between the cartilages, and which, like them, is inspiratory.

63. *Serratus magnus, expiratory above, inspiratory below.*

I observed in the Dog, as in the Ass, the superior fibres of the serratus magnus to be expiratory, the inferior inspiratory, and those fibres in the centre neutral, § 51.

64. *In the Dog : serrati postici, superior fibres inspiratory, inferior expiratory.*

The serratus posticus superior (fig. X. 10) was throughout inspiratory. The serratus posticus inferior (fig. X. 11) was expiratory, its depressing action on the ribs overbalancing any action it might have to draw them backwards. The Seal (fig. VIII.) has a middle serratus posticus. See § 53.

65. *In the Rabbit, both serrati postici are inspiratory.*

In the Rabbit (fig. XI.) I observed that both serrati postici were throughout inspiratory; indeed their fibres are so amalgamated that they form one muscle. The diaphragmatic ribs of the Rabbit, which are far apart, are drawn far backwards on inspiration by the combined influence of the serratus posticus and the levatores costarum.

66. *Expiratory muscles.*

I observed that the rectus abdominis, the external oblique, the transversalis, and the sacro-lumbalis, all acted on expiration.

67. *Varieties in the rectus, external oblique, and depressor of first rib.*

The rectus (16) is inserted in the Otter (fig. XII.), fleshy into the first rib ; in the Dog (fig. X.) and Monkey it is inserted into the sternum, its whole length, by a tendinous aponeurosis, from which arises a fleshy depressor of the first rib (16 *a.*). In the Rabbit (fig. XI. 16 *a.*) this depressor arises from the sternum and passes in front of the rectus ; it does the same in the Seal (fig. VIII. 15), but in this animal it forms the first fibre of the external oblique (17), which combines with fibres to the first (15), second (15 *a.*) and third (15 *b.*) costal cartilages, to form one vast external oblique inserted into all the ribs.

68. *The triangulares sterni and the transversales combine to form one large muscle.*

The triangulares sterni (19) form in the Dog[*], the Seal[†] and the Otter[‡] one continuous web with the transversales (20) ; in fact the triangulares sterni combine with the transversales to form one extensive muscular web, the vast constrictor of the chest and abdomen that arises from the posterior surface of the sternum, from the xyphoid cartilage and from the linea alba, and is inserted successively into the anterior extremities of all the ribs from the second to the lowest, which ribs it draws downwards and inwards during expiration to constrict the chest and abdomen.

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[*] Fig. XI. *b.* Archives of the Royal Society.

[†] Fig. VIII. *b.* ibid.

[‡] Fig. XIII. *b.* ibid.

69. *The Seal; great respiratory apparatus.*

The Seal (fig. VIII.), of all the animals we have yet considered, has by far the most capacious chest; compare its large breathing apparatus and small abdomen with the small chest and enormous paunch of the Rabbit (fig. XI.). The chest of the Seal admits of very great expansion and contraction. Its slender ribs and very long flexible costal cartilages, its peculiarly deep dorsal arch, the great size of its levatores costarum, and the development of its intercostals, its external oblique, transversales and sterno-costals, all combine to give it very great power both of expiration and inspiration. The respiratory development is entirely thoracic, the scaleni having less action from the neck in this than in any animal we have yet examined.

PORPOISE, Plate XXVI. fig. VII. §§ 70–77.

70. *The Porpoise has a large portion of lung in the neck.*

The Porpoise, to which we now turn, has a development of respiratory power far greater even than the Seal. In addition to the usual thoracic and diaphragmatic space for breathing, this animal has a large portion of lung occupying the neck; in this it contrasts remarkably with the Seal.

The whole build of the Porpoise corresponds with this great cervical respiration. Its cervical vertebræ are all amalgamated to form one bone, on which the head has but little motion. The first and the succeeding five ribs articulate with long, slender, almost bony costal cartilages or sternal ribs, having moveable joints at each extremity. The sternum is broad and hollow within. The diaphragmatic ribs are six in number; of these the superior only has a costal cartilage.

The first rib has, owing to its long double-jointed costal cartilage, very great play in respiration.

71. *A peculiar scalenus* (1 *a.*)*; the sterno-hyoid and sterno-thyroid, while they act on the first rib and sternum, also expand the lung in the neck.*

The lungs rise up into the neck almost as high as the base of the skull; they are almost surrounded by muscles, having in front very powerful sterno-hyoid (13) and sterno-thyroid (14) muscles, and to the side, and behind, a large and very peculiar scalenus (1 *a.*). This scalenus is like the half of a funnel or hollow cone; it arises tendinous from the base of the skull, descends, and soon forms a hollow fleshy web that increases as it descends, half embraces the large portion of lung in the neck, and is inserted into the whole circuit of the first rib, and the costal half of the first costal cartilage. There is yet another scalenus to the outside of this, which is much shorter and smaller, arises from the vertebral transverse process, and descends obliquely forwards to the first rib.

The sterno-hyoid, sterno-thyroid, and large scaleni, all join to complete a circuit embracing the lungs behind, in front, and on each side, the vertebræ being, of course, behind, the larynx and pharynx between the lungs. When these muscles all act together in inspiration, they raise the sternum, the first ribs, and their costal cartilages. The sternum moves forward, the first ribs and cartilages move sideways, and the whole circuit is increased, the brim of the chest being at once widened and deepened. As the sternum and costal cartilages move forwards and outwards, they carry forward with them the sterno-hyoid and thyroid muscles; and as the first ribs move outwards and backwards they carry the scaleni outwards and backwards, so that the same muscles that raise the sternum, first costal cartilages and first ribs, and increase the circuit they embrace, are in turn pushed forwards, outwards and backwards by the parts they raise, and the space for the lungs in the neck that they encircle is everywhere increased.

72. *The scaleni do not move the vertebræ laterally, though they draw them forwards and downwards in inspiration.*

In the Porpoise we have found that the scalenus is enormously developed although the cervical vertebræ are quite destitute of motion; in the Seal, whose neck is remarkably flexible, the scaleni are quite insignificant (§ 58). It is very evident that the scaleni do not act to draw the vertebræ to either side; how can they in the Porpoise? and in the Seal, whose neck is so bending, why are they not unusually developed? it is because they do not act on the vertebræ laterally, and because the mobility of the vertebræ would interfere with their action on the ribs.

We find all through that the scaleni are small in those animals whose necks are mobile, and large in those that have inflexible necks. Though the scaleni do not move the vertebræ sideways, they do draw them downwards and forwards, at the same time that they raise the first ribs. The two fixed points in fact approach each other.

73. *The combined triangulares sterni and transversales form one vast constrictor of neck, chest and abdomen, which rises into the neck.*

The development of the scalenus, sterno-hyoid and thyroid, to cause the expansion of the lungs in the neck, is counterbalanced during expiration by the development in a remarkable manner of the sterno-costal, or triangulares sterni muscles (see § 68)*. In the Porpoise, the upper portion of these muscles, that in all other animals rises only to the second rib, ascends quite into the neck, embraces the lower half of the cervical portion of lung, and is inserted into the whole circuit of the first rib. In the Porpoise, as in the animals we formerly examined (§ 68), the sterno-costal muscles unite with the transversales; and they unite to form an enormous muscle, one vast constrictor of the neck, chest, and abdomen. This combined muscle arises from the sternum and linea alba, and is inserted into all the ribs. With the aid of the other expiratory muscles, it constricts the neck, chest, and abdomen, and thrusts, through the intermedium of the abdominal viscera, the large and bulging diaphragm almost quite up into the neck.

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* Fig. XVI. *c.* Archives of the Royal Society.

74. *Special inspiratory muscles in the Porpoise,* Plate XXVI. fig. VII. 27.8.8.

There is no scalenus to any rib save the first; a muscle (27) passes from the cervical transverse process to three or four of the superior ribs that must act to raise them; and muscular fibres (8.8) pass from the first rib just below the insertion of the scalenus, and from the second rib to be inserted into the third, fourth and fifth ribs; these muscles are probably also inspiratory.

75. *The serrati postici are amalgamated,* fig. VII. 10.11.

The serrati postici are, in the Porpoise, amalgamated to form one muscle, or at least one tendinous web; the fibres to the lower edge of the sixth rib mingle with those to the upper edge of the seventh; the two fasciculi above are inserted into the upper edges of the ribs; those below into the lower edges.

76. *Internal oblique.*

The internal oblique passes from rib edge to rib edge to be inserted into the anterior ends of the seven lower ribs.

The great caudal muscle is attached to the five lowest ribs.

77. *Power of the Porpoise to remain long under water accounted for.*

The true source of the power enjoyed by the Porpoise to remain so long under water is, I conceive, its capability of renewing almost the whole volume of air that is contained in the lungs at each inspiration, as the complete preceding expiration leaves scarcely any adulterated air in the lungs.

The animal may descend under water with a far purer and far larger stock of air than land animals can, by any effort, obtain; of course when the animal dives very deep the quantity of air in the chest cannot be great.

MAN, §§ 78–100. Plate XXIX. figs. XIII. *a. b.*, XIV. *a. b.*, XV. *a. b.*

78. All the creatures we have hitherto examined are in some measure illustrative of the mechanism of respiration in Man. In some point or other he partakes in structure with each of them.

His three lowest, the floating ribs, resemble the simple vertebral ribs of the Snake. His sternum and costal cartilages are analogous to the sternum and spinal ribs of birds. In the possession of an intermediate set of three ribs, the sixth, seventh and eighth, whose cartilages are all linked together, and which partake of the functions of the thoracic set of five ribs above, and diaphragmatic set of four ribs below, he resembles the Calf, the Ass, the Sheep and the Pig. He has flexible and elastic costal cartilages fixed to the rib and hinging on the sternum, in common with the Seal, the Dog, and the Rabbit. He has a large portion of lung in the neck, like the Porpoise, subject to cervical respiration, and he possesses a clavicle and flat superior sternal bone, and other points that ally him with the Monkey. Having broken ground by examining the machinery of breathing in these creatures, we shall find little difficulty in investigating that machinery in Man.

The various drawings (figs. XIII. *a. b.*, XIV. *a. b.*, XV. *a. b.**) are from the human subject. They are in pairs and represent the same subject, and the same view before and after the lungs were distended.

The chest in Man is a cavity of ever-varying capacity, whose walls can be enlarged everywhere simultaneously. The domed roof rises, the floor descends, and the diameter between the walls is increased in every direction.

79. *Dorsal arch; the longest ribs are at the centre of the arch. Thoracic, diaphragmatic and intermediate sets of ribs.* Plate XXIX. fig. XIV. *a. b.*

In Man, as in all other Mammalia (see § 31), the lower part of the sternum is more distant from the spinal column than the upper; a gradual increase in the length of the ribs and the depth of the chest takes place from above downwards. The first rib is the shortest; the ribs progressively lengthen to the sixth; to it the seventh and eighth, which are the longest, are about equal; and the four lowest ribs gradually shorten, the lowest being the shortest.

Man, in common with the other Mammalia, has a dorsal arch (see diagram D 1 and D 2, § 32), the curves of which correspond with the varying lengths of the ribs. The upper curve looks forwards and downwards, and coincides with the gradual lengthening of the five superior ribs which are connected with the sternum by distinct cartilages, and which encompass and expand the upper portion and body of the lungs, and are the ribs of thoracic inspiration (see § 34). The lower curve looks forwards and upwards, and is adapted to the progressive shortening of the four lower ribs which are tipped with floating cartilages, and which enlarge the lower portion of the chest simultaneously with the descent of the diaphragm, and form the diaphragmatic set of ribs (see § 34.35). To the hollow of the arch, at its centre, are fitted the three longest ribs, the intermediate set, or sixth, seventh and eighth, that take part with the five superior ribs in thoracic, and the four inferior in diaphragmatic respiration. The cartilages of these three ribs are linked together, so that when the superior cartilage is raised, the rest necessarily follow.

80. *Changes in the situation of the ribs on inspiration.* Plate XXIX. figs. XIII. *a. b.*, XIV. *a. b.*, XV. *a. b.*

During inspiration the ribs approach to or recede from each other according to the part of the arch with which they articulate; the four superior ribs approach each other anteriorly, and recede from each other posteriorly; the fourth and fifth ribs, and the intermediate set move further apart to a moderate, the diaphragmatic set to a great extent. The upper edge of each of these ribs glides towards the vertebræ in relation to the lower edge of the rib above (§ 6.7), with the exception of the lowest rib, which is stationary.

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* Figs. XIX. *a. b.*, XXI. *a. b.*, XXII. *a. b.*, XXIII. *a. b.*, XXIV., XXV. in the Archives of the Royal Society.

The breadth of the chest is considerably greater in proportion to its depth, and the mass of the upper portion of the lungs is greater relatively to the lower portion in Man than in the other Mammalia. The ribs descend first outwards and backwards, then outwards and forwards, and finally forwards and inwards.

During inspiration all the ribs are raised except the lowest of them ; the diaphragmatic set (see diagram M^2, fig. XV. *b.*) are not raised so much as the thoracic or the intermediate sets. All the ribs are further apart from each other posteriorly in M 2, fig. XV. *b.* inspiration, than in M 1, fig. XV. *a.* expiration.

Diagram M.

1. Expiration. Dorsal view. 2. Inspiration.

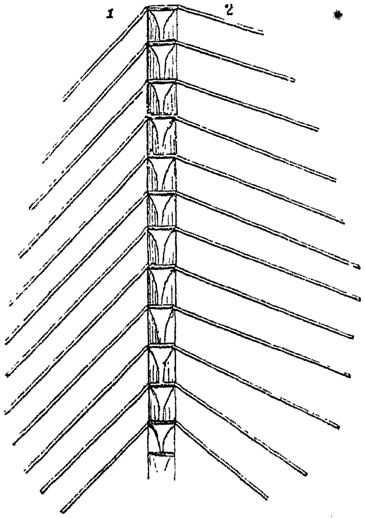
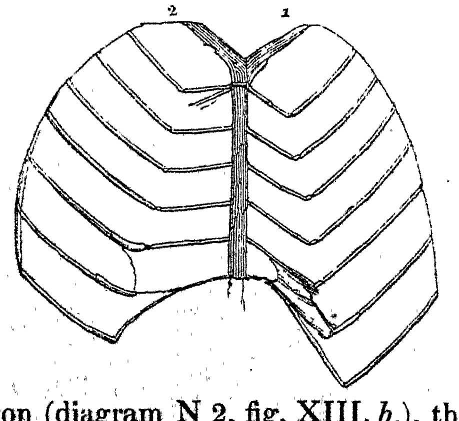


Diagram N.

2. Inspiration. Sternal view. 1. Expiration.



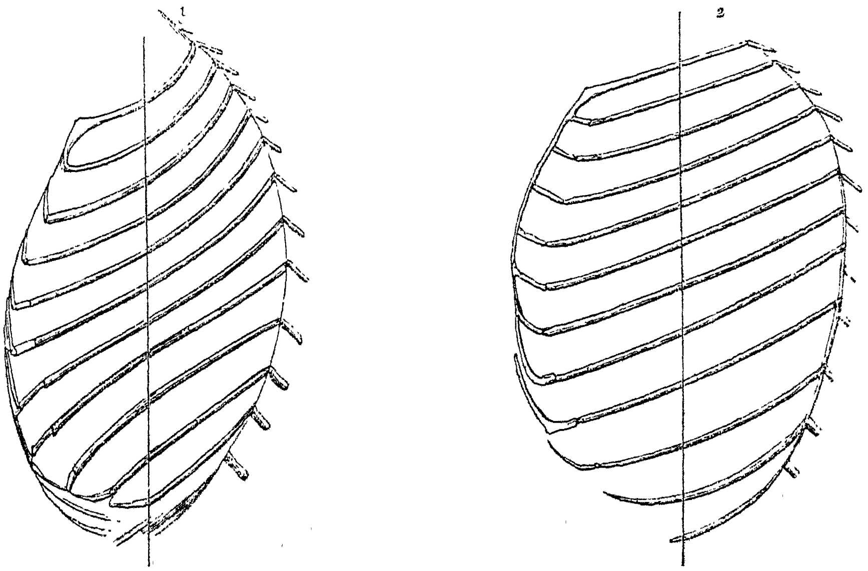
Anteriorly on inspiration (diagram N 2, fig. XIII. *b.*), the costal cartilages, which articulate by moveable joints with the sternum, are raised with the ribs ; the upper edge of each cartilage glides towards the sternum in relation to the lower edge of that above it. The second cartilage approaches the first rib, while the other cartilages become more remote from each other, and the angles formed by the ribs with the cartilages become more open. The breadth of the chest is much increased by the above movements. The cartilages of the intermediate and diaphragmatic sets of ribs of the opposite sides are drawn much further apart, and the distance between them in front is much increased. The angle between the opposite conjoint cartilages of the sixth and seventh ribs below the sternum is enlarged. See diagram N 1.2. and fig. XII. *b*, inspiration, contrasted with fig. XII. *a*, expiration.

On inspiration (see O 2, fig. XIV. *b*.) the anterior extremities of the ribs ascend and move forwards, and carry forwards and upwards the cartilages and the sternum. The posterior angles and extremities of the ribs move backwards and downwards and push backwards, and lower the spinal column. As the *longer intermediate ribs* occupying the hollow of the arch move backwards, from their greater length, more than the other ribs, *their immediate action is to deepen, and consequently shorten the dorsal arch.*

Diagrams.

O.

1. Expiration. Lateral views. 2. Inspiration.

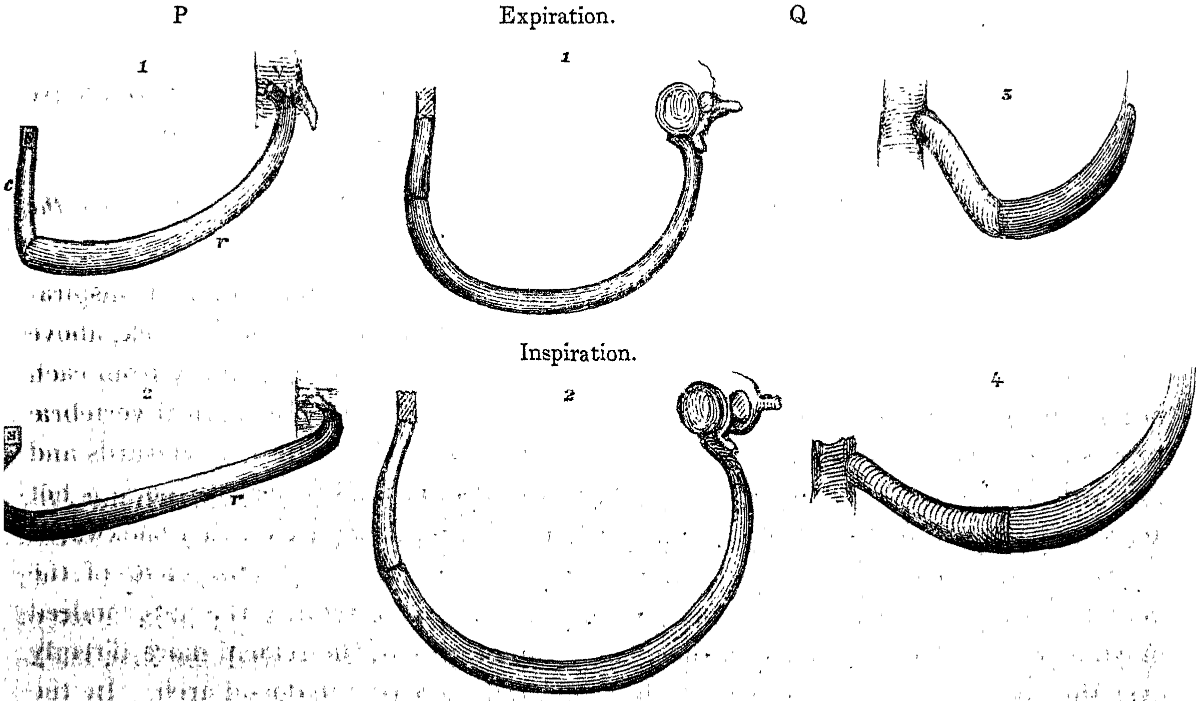


All those portions of the ribs in front of a line O 1.2, drawn from the insertion of the scalenus to the junction of the eleventh rib with its cartilage move forwards and ascend; all behind that line move backwards. This observation can be readily tested; place the thumb firmly on any part of the chest and breathe deeply; if in front of the line indicated, the thumb will be carried forwards; if behind the line, backwards.

On inspiration the costal cartilages (see diagrams P 2, Q 2, compared with P 1, Q 1) curve forwards on themselves, and deepen the concavities behind them to each side of the sternum. Owing to the change in position of the ribs, their outer curves are throughout enlarged, and the posterior curves to each side of the spine are deepened (§§ 39. 40. 55). The spinal column is pushed more and more backwards from the first to about the sixth or seventh dorsal vertebra, and less to the first lumbar. The posterior curves of the six or seven inferior ribs are deepened relatively to the spinal column, as is evidenced in diagram O 2, inspiration, compared with diagram O 1, expiration, in which the spines of the lower dorsal vertebræ are more concealed in the former than the latter by the posterior curves. The posterior curves of the diaphragmatic set of ribs are deepened more than those of the intermediate set, while those of the thoracic set, excepting the fifth rib, are not deepened at all; the whole of the backward thrust of those ribs being spent in pushing back the spinal column. The twelfth rib does not move backwards so far as the eleventh, hence there is not here the usual gliding motion of the lower rib on the upper. Each rib has its own peculiar difference in curves and surfaces fitting it for its precise place, all the ribs combining, by change in position, to present one set of curves and surfaces in expiration, another in inspiration.

The five superior ribs (the thoracic set) form as it were the dome and upper portion of the chest. On expiration, when the space they inclose is every way narrowed, the profile of the upper edge of each rib is concave (diagrams P 1, O 1, and fig. XIV. *a.*), the inner concavity is shallowed (diagram Q 1), and the oblique surface tends to the

Diagram representing the position of a rib in expiration and in inspiration.



P 1.2. Side views. Q 1.2. Views looking as it were down into the chest, a transverse section. Q 3.4. Front views.

vertical direction (see diagram R 1). On inspiration, when the dome and upper part of the chest are amplified in every direction, the profile of the upper edge of each rib is nearly straight (diagrams P 2, O 2, and fig. XIV. *b.*), the inner concavity is deepened (diagram Q 2), and the direction of the oblique inner surface becomes more nearly horizontal (diagram R 2).

On expiration, the sixth rib, or the upper of the intermediate set of ribs, is curved upwards, while the seventh is curved downwards. On inspiration, these two ribs move further apart, they each of them become parallel and assume an almost straight profile. The eighth or lowest of the intermediate set, and the ninth or uppermost of the diaphragmatic set of ribs, are on expiration curved downwards like the seventh, and like it they become more nearly straight on inspiration. The anterior ends of the sixth, seventh and eighth ribs, or the intermediate set, being linked together, are raised on inspiration exactly to the same extent, while the lateral portions of the seventh and eighth ribs are not so much elevated as is that of the sixth; the sixth being raised more, relatively, in the centre than at the anterior extremity, while the seventh and eighth are more raised at their anterior extremities than at the centre.

The curve of the profile of the ninth rib, or the first of the diaphragmatic set, is not so much lessened on inspiration as is that of the eighth, as the anterior extremity and centre of the ninth rib ascend to a proportional extent. The profile of the tenth rib is straight, while that of the two lower ribs is curved slightly upwards. The inner surfaces of the lower ribs, which in expiration are somewhat oblique, the obliquity looking upwards, take a vertical direction on inspiration.

§§ 81–95. *Muscular actions.*

81. The great complication of the movements of the ribs in respiration is of course met by like complication in the actions of the muscles that move those ribs.

82. *The scaleni raise the first and second ribs and lower and bring forward the cervical vertebræ. See* § 72.

The scaleni act to elevate the first and second ribs during the whole of an inspiration; their action may be easily felt by placing a finger on each side of the neck, above the clavicles; the fingers are gradually pushed outwards and further away from each other during the whole inspiration. While the scaleni act from the cervical vertebræ to raise the first rib, they, in turn, also act from the first rib to draw downwards and forwards the cervical vertebræ, § 72. This movement of the cervical vertebræ is not absolute but relative, for they, riding on the dorsal vertebræ, are carried backwards by the inspiratory movements of the latter; but the backward movement of the dorsal is considerably greater than that of the cervical vertebræ; the latter indeed move forward relatively to the former, carry the origins of the scaleni more directly over the points of the ribs on which they act, and increase the dorsal arch. In the difficult breathing of persons suffering from chest disease, I have seen the head and neck move forwards on each inspiration.

83. *The scaleni expand the cervical portion of lung. See* § 71.

In Man a considerable portion of lung is situated above the clavicles; the expansion of this portion of the lung is effected, as it is in the Porpoise (see § 71), by the mutual action of the scaleni and first rib on each other; while they raise the rib, the rib moves outwards and carries with it the scaleni; the scaleni then widen the space into which the lung rises and which they bound.

84. *Pleural scalenus**.

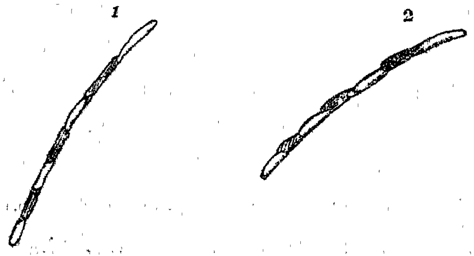
In addition to the ordinary scaleni, there is usually a special scalenus to expand the summit of each lung. This pleural scalenus arises from the transverse process of the seventh cervical vertebra, becomes tendinous and aponeurotic, and is inserted by a funnel-like tendinous web into the whole circuit of the first rib. The pleural scalenus somewhat resembles the large funnel-like scalenus of the Porpoise, that enlarges the lung in the neck, § 71.

85. *Intercostal muscles*, Plate XXIX. figs. XIII. *a.b.*, XIV. *a.b.*, XV. *a.b.* §§ 46.48.49.60.61.

The action of each intercostal muscle depends entirely on the movements of the rib into which it is inserted; as the thoracic set of ribs approach each other in front, while the diaphragmatic and intermediate sets recede from each other, we might have anticipated that the intercostal muscles between the former have different respiratory actions from those between the latter. We have already seen, in the lower Mammalia, how completely the actions of the intercostal muscles correspond with the motions of the ribs (§§ 48. 49. 60. 61.); we shall find the same correspondence in Man.

The external intercostals of the seven superior ribs (all the thoracic and two of the intermediate sets) are throughout inspiratory; they raise these ribs, make them to glide on each other towards the vertebræ (§§ 6.7), and push backwards, through the ribs, the vertebral column; those of the thoracic set, in addition, make the oblique inner surfaces of the ribs more nearly horizontal, as diagram R illustrates.

Diagram R.



Expiration. Inspiration.

The anterior or intercartilaginous portions of the superior five internal intercostals are all inspiratory (fig. XIII. *b*); they raise the costal cartilages and make them glide on each other towards the sternum; the four superior internal intercostal muscles are inspiratory anteriorly, where the ribs approach each other, and expiratory posteriorly, where they recede from each other; the rest of them are throughout expiratory; they depress the ribs, make the lower edge of each rib glide towards the vertebræ in relation to the upper edge of the rib below, and bring forwards the spinal column.

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* Fig. XXVI. Archives of the Royal Society.

At the upper and anterior part of the chest, where the ribs approach nearer to each other, an inspiratory shortening of the fibres of the internal intercostal overweighs the usual expiratory action (fig. XIV. *b*). There the external and internal intercostal muscles act simultaneously in a diagonal direction. (See § 48, last portion of it.)

The four inferior external intercostals inserted into the diaphragmatic set of ribs, are expiratory between the anterior and lateral portions of the ribs, where they are so far apart from each other as to overweigh the inspiratory gliding motion of the ribs towards the vertebræ, figs. XIII. *b*., XIV. *b*. (§ 49). Posteriorly near the spine they are all, save the lowest, inspiratory. See diagram M, fig. XV. *b*. The fibres inserted into the ninth costal cartilage cause it, during inspiration, to glide downwards and backwards on the cartilage above; so that the anterior or intercartilaginous fibres of the eighth external intercostal are inspiratory, while the lateral fibres between the ribs are expiratory, and the posterior fibres are inspiratory (figs. XIII. *b*., XIV. *b*., XV. *b*).

The seventh external intercostal, that of the lowest of the intermediate set, has its anterior fibres slightly shortened on expiration; its posterior, on inspiration. The whole of the lower internal intercostals are throughout expiratory, whether between the ribs or the cartilages; they make each lower cartilage glide forwards and upwards on the cartilage or rib above.

86. *Levatores costarum.*

The levatores costarum, which are nearly allied, almost identical, with the external intercostals, are all inspiratory; they elevate the ribs posteriorly, and the inferior muscles draw backwards and deepen the posterior curves of the ribs. See diagram B, § 9. The superior levators are but insignificant; the ribs on which they act, although they are raised considerably, have no backward movement. The six or seven lower levators are of considerable size; the ribs on which they act, though they are raised but little, are drawn backwards considerably (fig. XV. *a*.*b*). See § 50.

87. *Serratus magnus, chiefly expiratory. See* §§ 51. 63.

The serratus magnus, and the serratus posticus inferior, are the only other muscles besides the external and internal intercostals, that have, in some portion of them, an inspiratory, in others, an expiratory action. In the Dog (§ 63) and Ass (§ 51) the superior fasciculi of the serratus magnus are expiratory; the inferior are inspiratory; and the central fibres are neutral.

In Man the greater portion of the fasciculi of the serratus magnus act visibly in violent expiration. Indeed, from the direction of the superior fasciculi, they must be expiratory*; the two or three lower fasciculi, from their direction, probably act in deep inspiration; but I have not observed them to do so.

88. *Serratus posticus inferior, expiratory. See* §§ 53. 64. 65.

In the Ass (§ 53) the four lower fasciculi of the serratus posticus inferior are inspiratory, the two upper expiratory, and the two intermediate neutral. In the Dog (§ 64) all the fasciculi are expiratory, while in the Rabbit (§ 65) they are all inspiratory. From the direction of the fibres, and from the fact that the fibres are shorter when the lungs are flaccid than when they are distended, I infer that in Man the serratus posticus inferior is expiratory.

89. *Inspiratory muscles, ordinary respiration.*

I have observed the following muscles to be inspiratory. In ordinary inspiration, the levator anguli scapulæ draws the scapula upwards away from the ribs so as to allow them unembarrassed play. The serratus posticus superior (I have seen it act in the Dog and the Ass) draws upwards and outwards the superior ribs into which it is inserted.

90. *Deep or difficult inspiration.*

In deep or difficult inspiration, the superior fibres of the trapezius assist to elevate the scapula.

The sternum is raised by the sterno-cleido-mastoid and by the sterno-hyoid and thyroid muscles; the origins of the latter take their bearings from the inferior maxillary bone, through the active intermedium of the genio-hyoid and the anterior belly of the digastricus.

The pectoralis minor and the lower fibres of the pectoralis major raise the ribs to which they are attached.

91–94. *Muscles of expiration.*

91. In addition to the intercostal muscles, the greater portion of the serratus magnus, and I believe the serratus posticus inferior, the following muscles act during expiration (I have seen them act in the Dog and Ass, §§ 51. 53. 54. 63.).

92. *Expiratory muscles acting on the scapulæ.*

The latissimus dorsi.—I have seen it act in Man in difficult expiration, especially in coughing, and I have also noticed it act on expiration in the Dog; it never contracts under any circumstances in inspiration. The latissimus draws the scapula forcibly downwards on the ribs; it is antagonist to the levator anguli scapulæ.

In coughing, the latissimi are assisted in their action on the scapulæ by the pectoralis major and the lower fibres of the trapezius; at the same time, while the serratus magnus is in action, the rhomboidei will doubtless draw the scapula backwards. Through the combined actions of these muscles the upper part of the chest is compressed by the scapulæ.

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* See QUAIN's Plates of the Muscles, Pl. XIII.

In violent coughing and in epileptic fits, many of the muscles of the limbs act with great power.

93. *Expiratory muscles acting on the ribs.*

The recti draw down the sternum, and with it the annexed costal cartilages and their ribs.

The external oblique draw downwards the eight inferior ribs, bring forwards and downwards the posterior portions of the ribs, and compress the abdomen.

The internal oblique draw downwards and backwards the anterior extremities of the inferior ribs and their cartilages, and compress the abdomen.

The two oblique muscles, the external and internal, combine to pull downwards the lower ribs; the external oblique draws the posterior curves of the ribs forwards, the internal oblique draws the anterior portions of the ribs and the cartilages backwards.

94. *The triangulares sterni and the transversales combine to form one large muscle, the constrictor of the chest and abdomen. See* §§ 68. 73.

We have already seen that the transversales combine with the triangulares sterni to form one vast constrictor of the chest and abdomen in the Porpoise, the Dog, the Seal and Otter.

I find that the transversales and triangulares sterni combine in like manner in Man; these muscles are indeed perfectly continuous and form one web*.

The combined transversales and triangulares sterni may be described as one muscle; the constrictor of the chest and abdomen, arising from the two lower thirds of the sternum, the xyphoid cartilage, and the linea alba, and inserted into all the ribs, except the first, close to their cartilaginous attachments. The fibres of this vast web combine to narrow the space between all the opposite ribs; they cause the costal cartilages connected with the sternum to bend on the ribs and on themselves; they constrict at once the space between the thoracic, intermediate and diaphragmatic sets of ribs, and indeed the whole chest and abdomen.

The combined actions of the recti, the external and internal oblique, and the transversales compress the abdominal viscera, and thrust them upwards against the diaphragm so as to elevate it.

The sacro-lumbalis and the longissimus dorsi act with the quadratus lumborum to draw downwards the posterior portions of the ribs.

We have then a very powerful array of expiratory muscles; they are much more powerful than the inspiratory, as I previously inferred, and as has been proved by

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* Fig. XXVI. Archives of the Royal Society.

Mr. Hutchinson, whose ingenious inquiries have thrown much light on the mechanism of breathing.

In every act of violent exertion, in lifting weights, in coughing, laughing and crying, in the violent convulsive fits of epilepsy, and in many other energetic acts, the vocal chords are forcibly closed by muscular actions; the air cannot be expired, and the expiratory muscles all combine in the attempt to force out the air from the lungs, but ineffectually till the vocal chords are separated. The muscles of the limbs have an admirable fixed point for the centre of their actions, when the chest is rigid with this violent but ineffectual straining at an expiration.

95. *The diaphragm.*

It is not my intention in this paper to describe minutely the form and respiratory actions of the diaphragm; but this muscle must not be passed over, as it plays so important a part in the breathing machinery, and modifies so much the form, the number and the movements of the lower set of ribs, or those that assist in diaphragmatic respiration.

I have seen the action of the diaphragm in the Dog, the Ass, the Rabbit, and the domestic Fowl. The form and position of the diaphragm depend entirely on the relative proportion of the lower and posterior, or diaphragmatic, to the upper and anterior, or thoracic portion of the lung.

In the Ass, the upper or thoracic portion of lung is very narrow and has but little play; the diaphragmatic portion is of great bulk and expansibility posteriorly; there is but a small extent of lung anteriorly. The diaphragm is very oblique, tending to the vertical direction; its anterior fibres are strong but short; its lateral fibres are long; they are inserted into an oblong central tendon. When the diaphragm acts, the diaphragmatic portion of the chest is expanded behind and to the side. The body and lower or posterior portion of the diaphragm moves forwards and downwards to a great extent, the anterior portion descends very little, and the whole muscle becomes comparatively flattened, § 35.

In the Dog, the upper or thoracic portion of the lungs is much expanded on inspiration; the lower surfaces of the lungs and the diaphragm are almost horizontally concave. The diaphragm has long muscular fibres anteriorly; its descent being almost as great anteriorly as posteriorly, § 35.

In Man, the diaphragm is oblique, approaching the horizontal direction. The right side is larger and bulges higher into the chest than the left. From the floor of the pericardial sac is given off a strong tendinous web that sheaths the whole pericardium and is inserted into the investments of the great vessels at the upper part of the chest. A thin aponeurosis ascends over each pleura, another descends on the peritoneum. A strong tendinous sheath rises from the central tendon, surrounds the vena cava hepatica, and invests all its branches. On inspiration, the bulges of the diaphragm are first flattened, and then the whole muscle descends to a nearly equal extent. The central tendon in its descent stretches and elongates the pericardial sac, increasing the space containing the heart. When the diaphragm is forced up by the contraction of the abdominal muscles, the tendinous fibres with which it invests the vena cava, interstitially support the mass of the liver.

96–100. *Varieties in the mechanism of respiration in the human subject due to age and sex.*

96. In the human subject the extent of the lung varies with the age and sex of the individual. In the adult well-formed man, the chest is apparently of greater bulk than the abdomen. The proportion of the chest to the abdomen is greater in the active than the inactive.

97. *Female*[*].

In the female the development of the abdomen in relation to the chest is considerably greater than it is in man. Owing to the tightness with which the stays are usually worn round the lower or diaphragmatic portion of the chest, the diaphragm is compressed and its inspiratory expansion is greatly impeded. The opposite conjoint cartilages of the sixth, seventh and eighth ribs (the intermediate set) are pressed nearer to each other, so that instead of forming an angle with each other, they become almost parallel. To make amends for the artificial impediment to respiration of the diaphragmatic portion of the lungs, the thoracic portion is unnaturally developed.

98. *Fœtus*[†] *and new-born infant*[‡].

In the child[§], and still more in the fœtus and new-born infant, the abdomen and its viscera are very large in proportion to the chest and its contents. While the lungs are small, the liver is of great size.

In the fœtus, the unexpanded lungs occupy a very small space; the sternum and costal cartilages fall inwards and form a hollow; the angle between the opposed sixth, seventh and eighth costal cartilages below the sternum is obtuse, and the abdominal viscera push outwards the inferior ribs to a very great extent.

In the new-born infant the sternum and costal cartilages, by virtue of their elasticity and of muscular actions, move forwards, and from being concave become flat or slightly convex; the sixth, seventh and eighth cartilages form with each other a right angle.

Influence of the elasticity of the walls of the chest on the first inspiration and on respiration.

The inspiratory expansion of the chest in the new-born infant illustrates well the effect of the elasticity of the thoracic walls in maintaining a considerable portion of air in the lungs. By no muscular effort can a child that has once breathed force out the whole of the air from its lungs. If we compress the chest after death, a portion of air is pressed out through the trachea; on removing the pressure the resiliency of the walls of the chest draws as much air into the lungs as was previously expressed; an incomplete but artificial inspiration can thus be performed. A very simple apparatus, acting on this principle, is recommended in the Humane Society's Report for 1834, p. 126. The chest is compressed by a many-tailed bandage, the tails of which cross each other; when they are alternately tightened and relaxed they excite artificial respiration. A syringe has been constructed to act on the same principle; after it draws a portion of air out of the lungs through the trachea, fresh air, being admitted, rushes in to supply its place; in both these cases the lungs are expanded by the elasticity of the parietes of the chest.

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[*] Fig. XIX. Archives of the Royal Society.

[†] Fig. XXIV. Archives of the Royal Society.

[‡] Fig. XXV. Ibid.

[§] Fig. XXI. XXII. Ibid.

I conceive that respiration after the first breath is essentially performed by muscular actions; at the end of each expiration the elasticity of the walls of the chest will tend to commence the next inspiration; until the walls of the chest arrive at the medium size, or that which they retain after death, the elasticity will act along with the muscles; as soon as they have passed beyond this point, the elasticity will tend to act against the muscular actions; indeed these have to overcome the elasticity. At the end of an inspiration, elasticity will commence the expiration, assist in the action up to the neutral point, and resist it beyond that point. Thus elasticity as an agent in respiration balances itself.

I would not have remarked on the elasticity of the walls of the chest as a respiratory agent, but for a short note from Mr. HUTCHINSON, informing me that he was inquiring into the subject. From the success of his previous inquiries I look forward to his communication with much interest.

99. *The child**.

In the child, the liver and the stomach, and other abdominal viscera push the diaphragmatic set of ribs and the cartilages of the intermediate set forwards and outwards, and cause them to project beyond the thoracic set of ribs, as the girt of the abdominal organs is considerably greater than that of the thoracic. When the diaphragm descends, the lungs and heart occupy the place previously taken up by abdominal viscera, and as the lungs are smaller than the viscera they replace, the lower end of the sternum and xyphoid cartilage, the conjoint cartilages of the sixth and seventh ribs, and the sixth rib fall backwards on inspiration owing to the pressure of the atmosphere. If the inspiration be so deep as to bring the lungs down to the lower edge of the floating cartilages, all those cartilages fall backwards also, and those of the opposite side approach each other.

As the proportion of the abdominal to the thoracic viscera lessens as life advances, the lower cartilages gradually cease to fall backwards during inspiration, and after wards, as the proportion of the thoracic to the abdominal viscera increases, a forward movement of the lower cartilages takes place; this gradually increases until, in adult life, the forward movement of the conjoint cartilages and of the lower portion of the sternum is even greater than that of the superior cartilages and the upper portion of the sternum.

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* Figs. XXI. *a.b.*, XXII. *a.b.* Archives of the Royal Society.

100. *Old age**.

In the aged, the costal cartilages being ossified, each rib and cartilage forms as it were one inflexible bone; the costal cartilages still hinge on the sternum. The costal respiration is performed by the elevation and consequent variation in the position of the curves of the ribs. There is no yielding of the cartilages, consequently the lower part of the sternum and the conjoint costal cartilages are pushed forward to a greater extent than they are in the youthful. The thoracic respiration, though considerable, is not so great as in the adult or young man; to make amends, diaphragmatic respiration is increased, and the angle formed between the opposite costal cartilages below the sternum is more open. The old man does not require the energetic breathing of the young. The bulk of the lung increases, the air-cells being enlarged, in the aged, and the chest gradually takes on more and more the form that it has on an ordinary or even a deep inspiration; consequently the movement of the ribs on inspiration is not so great in the old man as it is in the middle-aged. The increase of the dorsal arch due to the permanent inspiratory form, causes the stooping, and, in part, the shortening of the aged.

101. *Varieties in respiratory movements induced by disease.*

Permit me to hint at the influences of some diseases of the lungs on the respiratory movements of the chest.

If the larynx be narrowed so as to permit but little air to enter the lungs, the diaphragm descends so rapidly that the air has not time to fill up those portions of the lungs displaced downwards by the diaphragm; the consequence is that the pressure of the atmosphere forces backwards and inwards the costal walls on the lungs.

If the summit of the lung be affected with phthisis, the corresponding portion of the chest is but little dilated, and the ribs are depressed and almost motionless over the diseased portion of lung; sometimes the rib even falls in at the beginning of inspiration.

In inflammation of the lower lobe of the lung, that lobe is distended by diseased secretions; the chest over it is permanently expanded and has little or no respiratory movement; at the same time the upper portion of the same side of the chest is less actively inspiratory.

If the diaphragm be inflamed on one side, that side does not act; the diaphragmatic ribs and the hypogastric region do not move forwards on the affected, though they do on the healthy side.

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* Fig. XXIII. *a.b.* Archives of the Royal Society.

If any part contiguous to the ribs, on one side, would be injured by the respiratory motion of those ribs, then that side of the chest is often motionless, though the lung be sound.

If the air-cells be dilated, the whole chest takes on permanently the form that it has on a deep inspiration.

These instances show the practical value of a thorough knowledge of the healthy respiratory movements of each portion of the chest; the attention is at once called to any point that, owing to disease, has not its due motion.

The above paper relates almost exclusively to the mode in which the movements of the ribs expand and contract the chest in respiration; the diaphragm is only treated of incidentally. The remarkable series of respiratory movements that take place in the nostrils, lips, mouth, palate and tongue, in the larynx and pharynx, and in the cervical fasciæ, are not even mentioned.

On a future occasion I hope to investigate those parts of the mechanism of respiration that are here only briefly alluded to, or altogether omitted.

SUMMARY.

Demonstrative proof of the statements in the following summary is, I believe, advanced in the preceding paper and its accompanying drawings.

The Snake (§§ 3–11. Plate XXIII. figs. I. II.) has the most elementary form of ribs. They are all alike, and are only attached at their vertebral end, their anterior ends being free (§ 4). There are neither sternum nor costal cartilages.

When the lungs are expanded, the levatores costarum, and the external intercostals raise the ribs, widen the spaces between them, make their anterior ends move forwards, and cause the upper edge of one rib to glide backwards in relation to the lower edge of the rib above it. Diagram A 1.2, fig. I. *a.b.* §§ 4. 6. 7. 10. The scalenus acts on the first rib.

The levatores costarum draw the ribs backwards behind, outwards to the side. Diagram B 2, § 9.

When the lungs are emptied the movements of the ribs are exactly reversed by the long depressors of the ribs, and by the internal intercostals and the transversalis. Diagram A^1, B^1, §§ 6, 11.

In Birds (§§ 17–27. Plate XXIV. XXV. figs. III.–VI.) a sternum and sternal ribs are coupled with the vertebral ribs and vertebræ to complete the circuit of the chest (§ 17).

The respiratory movements, and the muscles exciting the movements of the sternal ribs on the sternum and on each other, are exactly the same in principle, though reversed in direction, with those of the vertebral ribs on the vertebræ and on each

other. Diagram C 1.2, figs. VI. *a.b.* § 18. On inspiration, the angles between the vertebral and sternal ribs become more open; the sternum moves forwards and the spinal column slightly backwards, and the chest is slightly expanded. These movements are effected by the combined action of the scaleni and sterno-costal muscles on the first vertebral and first sternal ribs respectively; of the levatores costarum and external intercostals on all the lower vertebral ribs; and of the sternal intercostals on all the lower sternal ribs. §§ 19. 20. 23. 24. fig. VI. *b.* diagram C 2.

On expiration, the movements are reversed by the internal intercostals, the external and internal oblique, recti, transversales, and other muscles. § 26, fig. VI. *a.* diagram C 1.

In the Mammalia (§§ 28–100. Plates XXVI.–XXIX. figs. VII.–XV[*].) the addition of a large and efficient diaphragm—that in the Bird is small—modifies the form and varies the movements of the ribs and actions of the muscles in different parts. The ribs articulate with a dorsal arch (§ 31. X. *c.*); they vary in length, those hinging on the centre of the dorsal arch are the longest; while those on the superior curve gradually shorten from below upwards; those on the inferior curve shorten from above downwards. Diagram D 1.2. O. 1.2. figs. XIV. *a.b.* §§ 31. 32. 33.

By virtue of this arrangement, the ribs, articulating with the superior curve, when they are raised, approach each other anteriorly. These ribs have each a cartilage articulating with the sternum, that is analogous to the sternal rib of birds; they comprise the thoracic set. § 34. 35 Ass, §§ 67 Dog, 79 Man.

The ribs that hinge on the inferior curve of the dorsal arch, when raised, recede from each other; they have floating cartilages, and are the diaphragmatic set of ribs. §§ 34. 35. 67. 79.

Intermediate are the longest ribs connected with the dorsal arch; their cartilages are usually linked together and articulate with the lower end of the sternum; they, when raised, usually recede slightly from each other. Diagram N^2, fig. XIII. *b.* All the ribs recede from each other behind (Diagram M^2, fig. XV. *b.*). The anterior portions of the ribs move forwards and upwards, and carry with them the costal cartilages and the sternum (O. 2. fig. XIV. *b*). The posterior portions of the ribs move backwards, push backwards the vertebræ, and deepen the dorsal arch. Diagram O, fig. XIV. *b.*

The scaleni invariably act during the whole time of an inspiration (§§ 47. 58. 82); and in Man and the Porpoise they expand the portion of lung in the neck (§§ 71. 83), assisted in Man by the pleural scalenus (§ 84). They do not draw the cervical vertebræ to either side, but they draw them, during inspiration, forwards and downwards (§§ 72. 82).

The external intercostals between the thoracic set of ribs are throughout inspiratory (§§ 48. 60. 85); those portions between their cartilages are expiratory (§ 60); between the diaphragmatic set of ribs they are inspiratory behind, expiratory to the side and in front; and between their cartilages they are inspiratory (§§ 49. 60. 85); between the intermediate set of ribs they are for the most part slightly inspiratory between the ribs, and expiratory in front between the cartilages (figs. XIII. *a.b.*, XIV. *a.b.*, XV. *a.b*).

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[*] And numerous additional drawings in the Archives of the Royal Society.

The internal intercostals of the thoracic ribs are expiratory behind and inspiratory in front, if the ribs approach there, and are inspiratory between their costal cartilages. Between the diaphragmatic and intermediate sets of ribs and between their cartilages, they are throughout expiratory (§§ 48. 49. 61. 85, figs. XIII.–XV.). The levatores costarum draw the posterior portion of the lower ribs backwards (§ 86, diagram B, fig. XV. *a.b*).

In the Ass and Dog, the upper fasciculi of the serratus magnus are expiratory, the lower inspiratory, and the intermediate neutral (§§ 51. 63). In Man, the greater part of the fasciculi are expiratory (§ 87).

In the Ass, the lower fibres of the serratus posticus inferior are inspiratory and the upper expiratory (§ 52); in the Dog, and I believe in Man, they are throughout expiratory (§ 88).

The following muscles I have observed to be *inspiratory*, in addition to those named above:—

On a moderate inspiration, § 89.—

The levator anguli scapulæ;

The serratus posticus superior.

On a deep or difficult inspiration, § 90,—

The superior fibres of the trapezius;

The sterno-cleido mastoid;

The sterno-hyoid and thyroid, with the genio-hyoid and digastricus;

The pectoralis minor;

The pectoralis major, its lower fibres.

The following muscles I have observed to be *expiratory*, in addition to those named above (§ 93. 94).

The latissimus dorsi draws down the scapula in coughing; the trapezius, its lower fibres, the pectoralis major and the rhomboidei (inferred) combine with the latissimus dorsi and the serratus magnus to draw the scapula forcibly downwards and forwards on the ribs. The recti and the external and internal oblique draw downwards the sternum and the ribs; the external oblique draw the posterior portion of the ribs forwards, the internal oblique their anterior portions backwards.

The transversales and the triangulares sterni combine together to form one muscle, *the compressor of the chest and abdomen* arising from the sternum, xyphoid cartilage and linea alba, and inserted into all the ribs but the first (§§ 68, 94); in the Porpoise it rises into the neck, and is inserted into all the ribs, § 73.

The sacro-lumbalis and the longissimus dorsi.

The expiratory muscles are, combinedly, more powerful than the inspiratory.

Fig. I.
Snake.

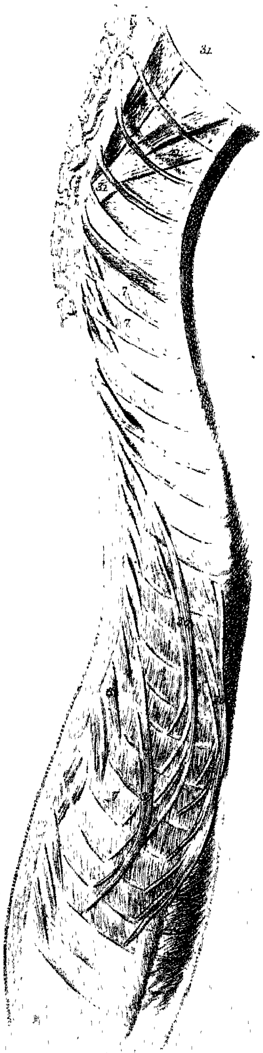


Fig. II
Chameleon.

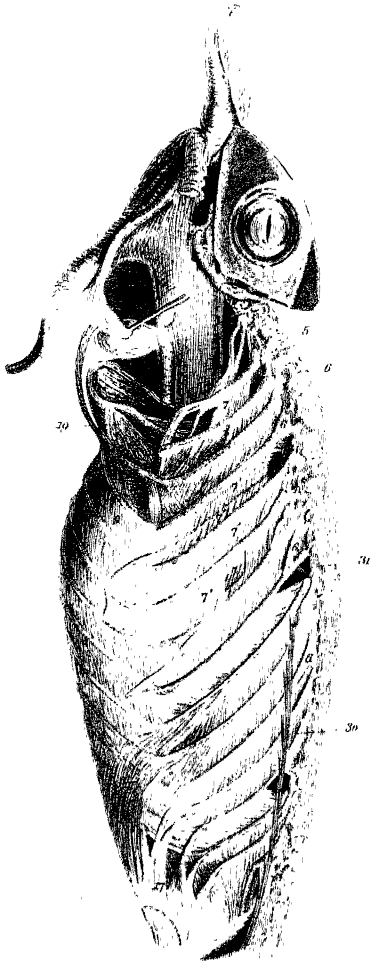
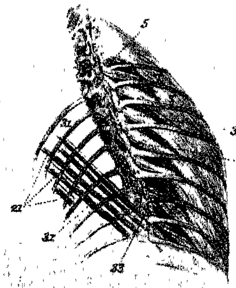


Fig. Ib.



on del. J.B

Fowl.

Fig. III a.

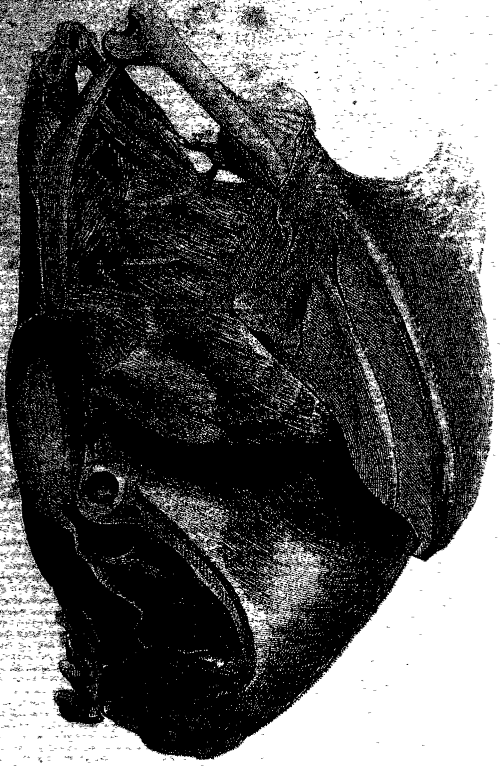


Fig. III b.

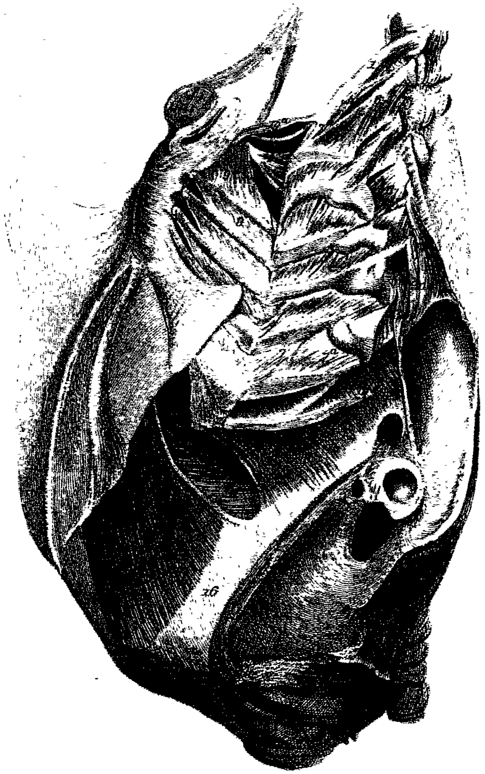


Fig III c.

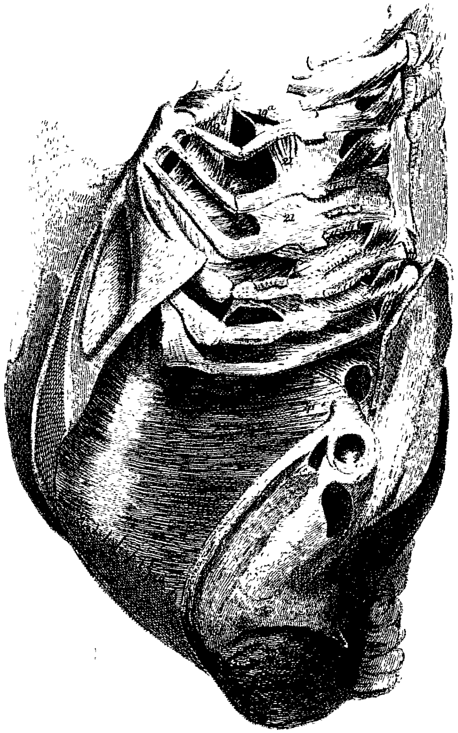


Fig. IV.
Hawk

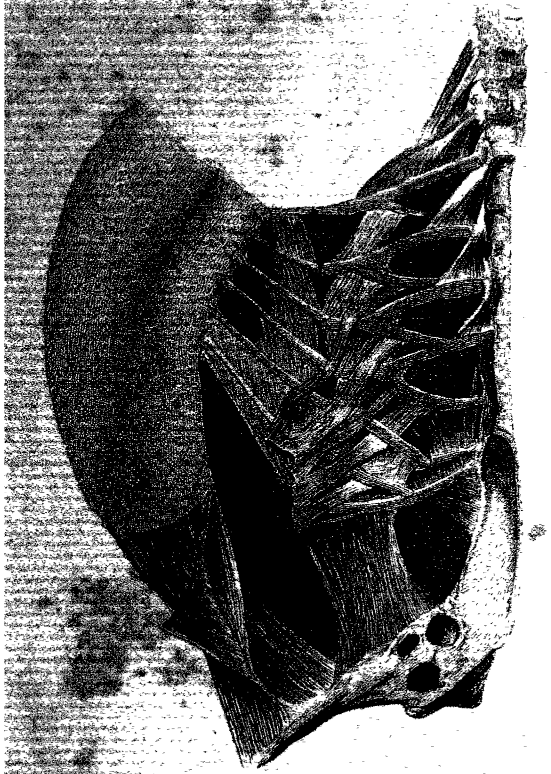
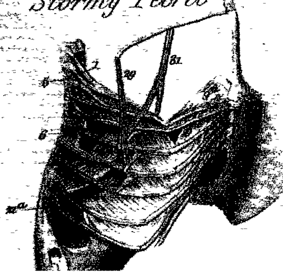


Fig. V.
Stormy Petrel



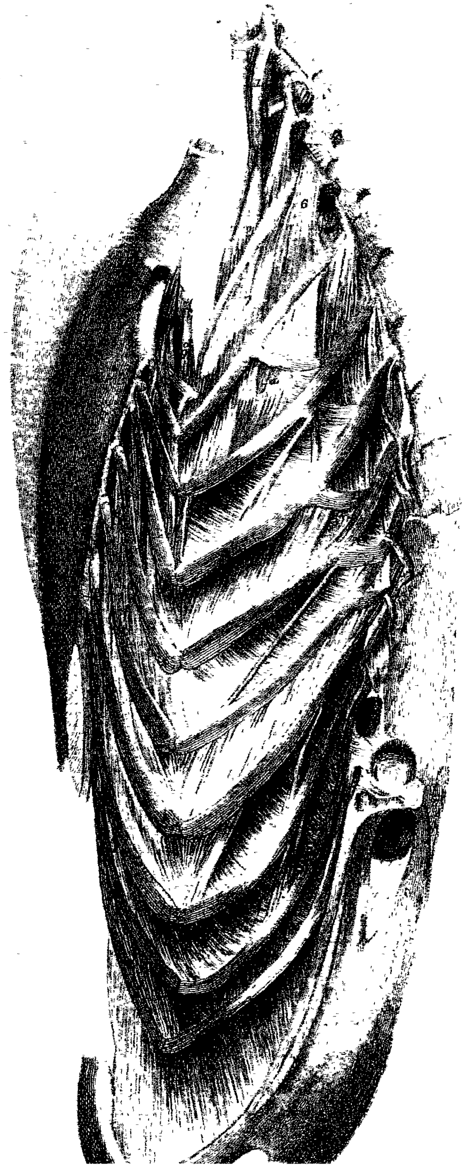
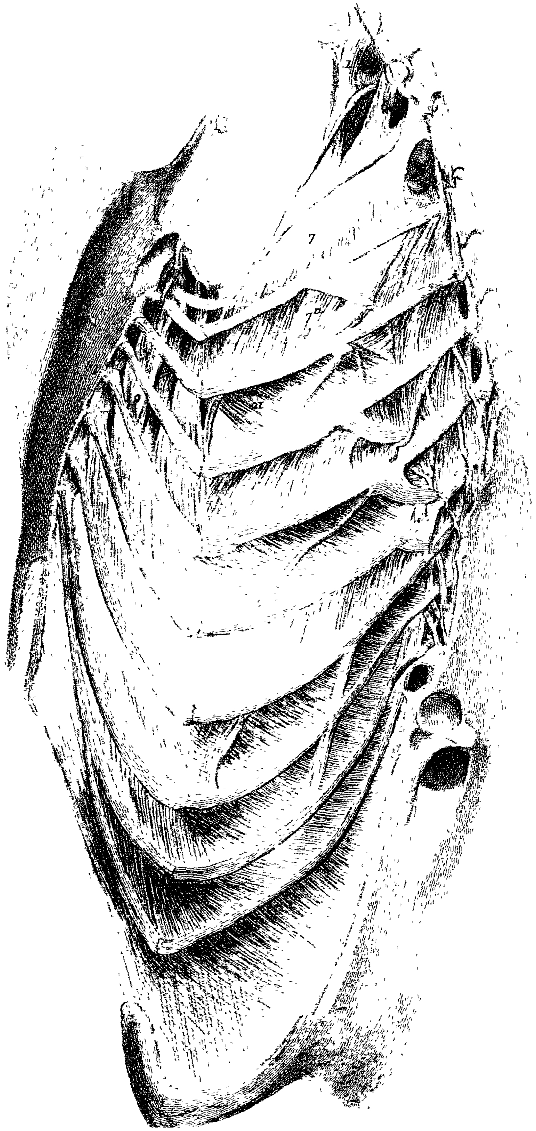
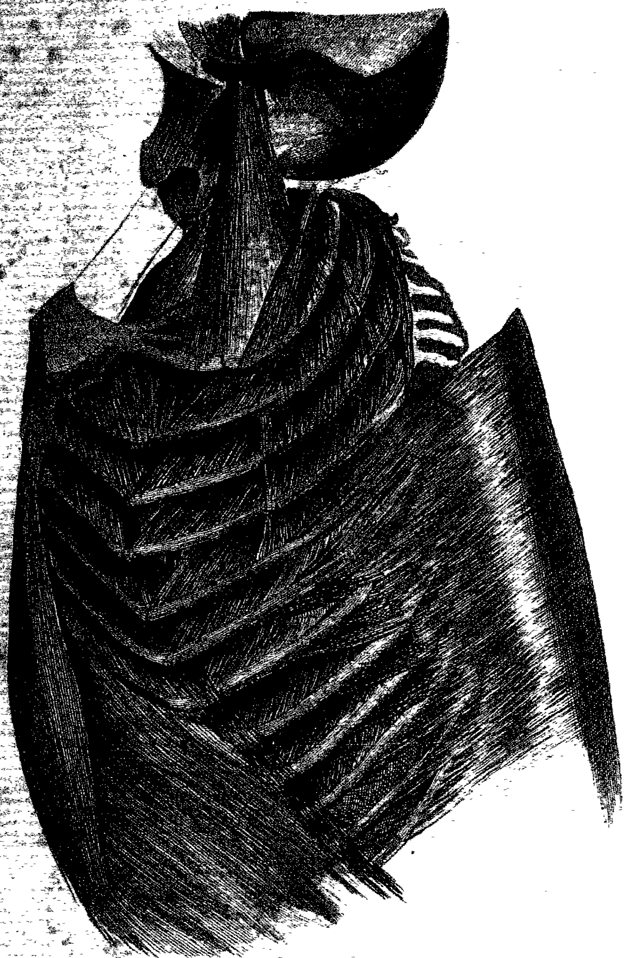


Fig. VI b.
Inspiration.



Porpoise.



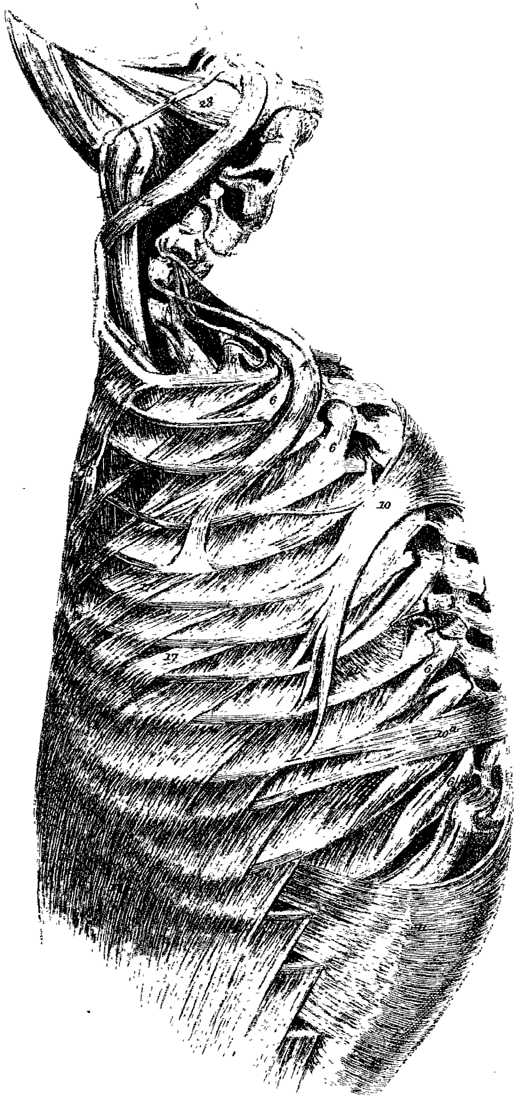


Fig IX

Calf

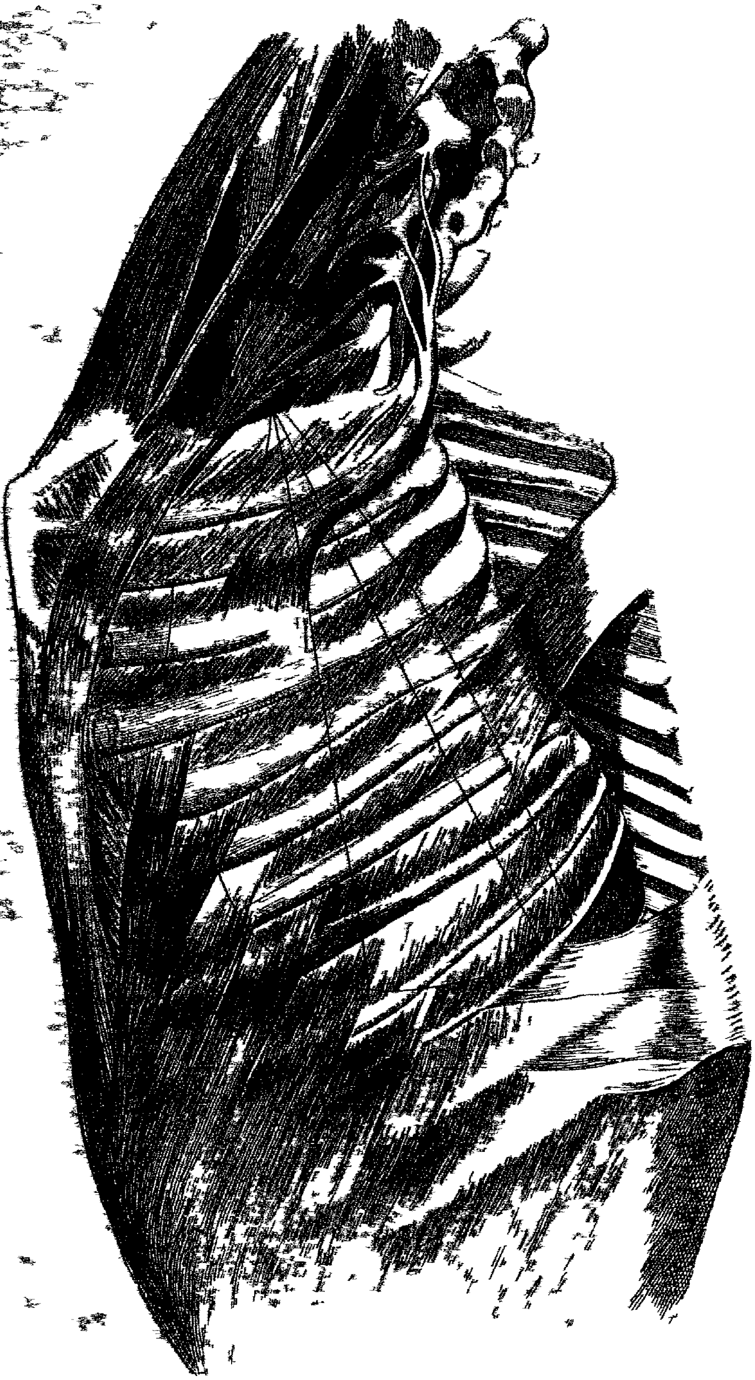
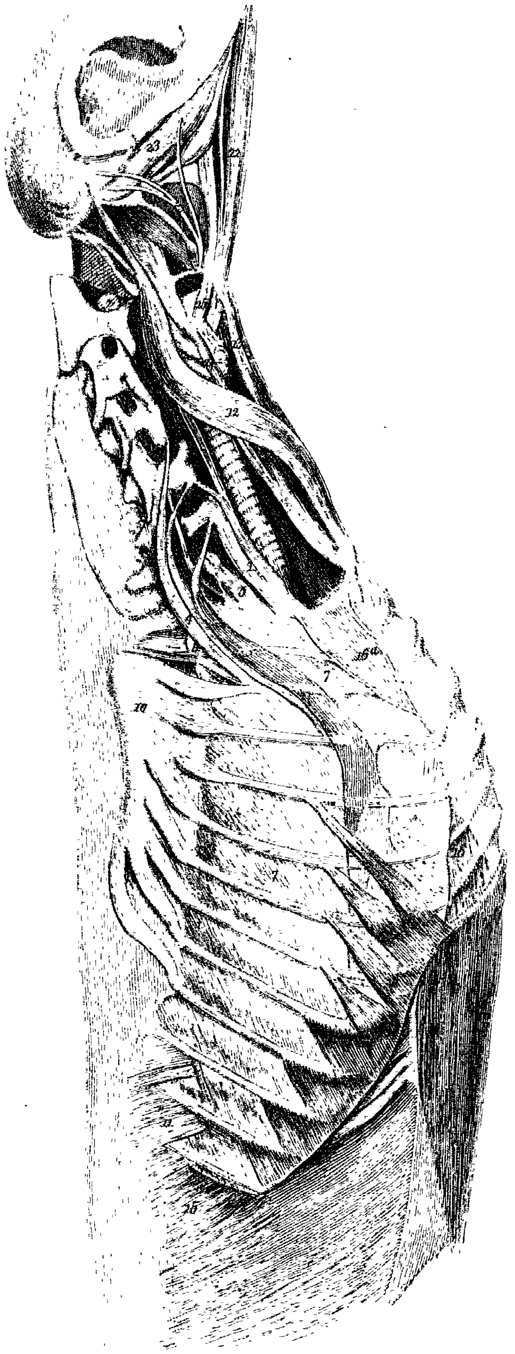
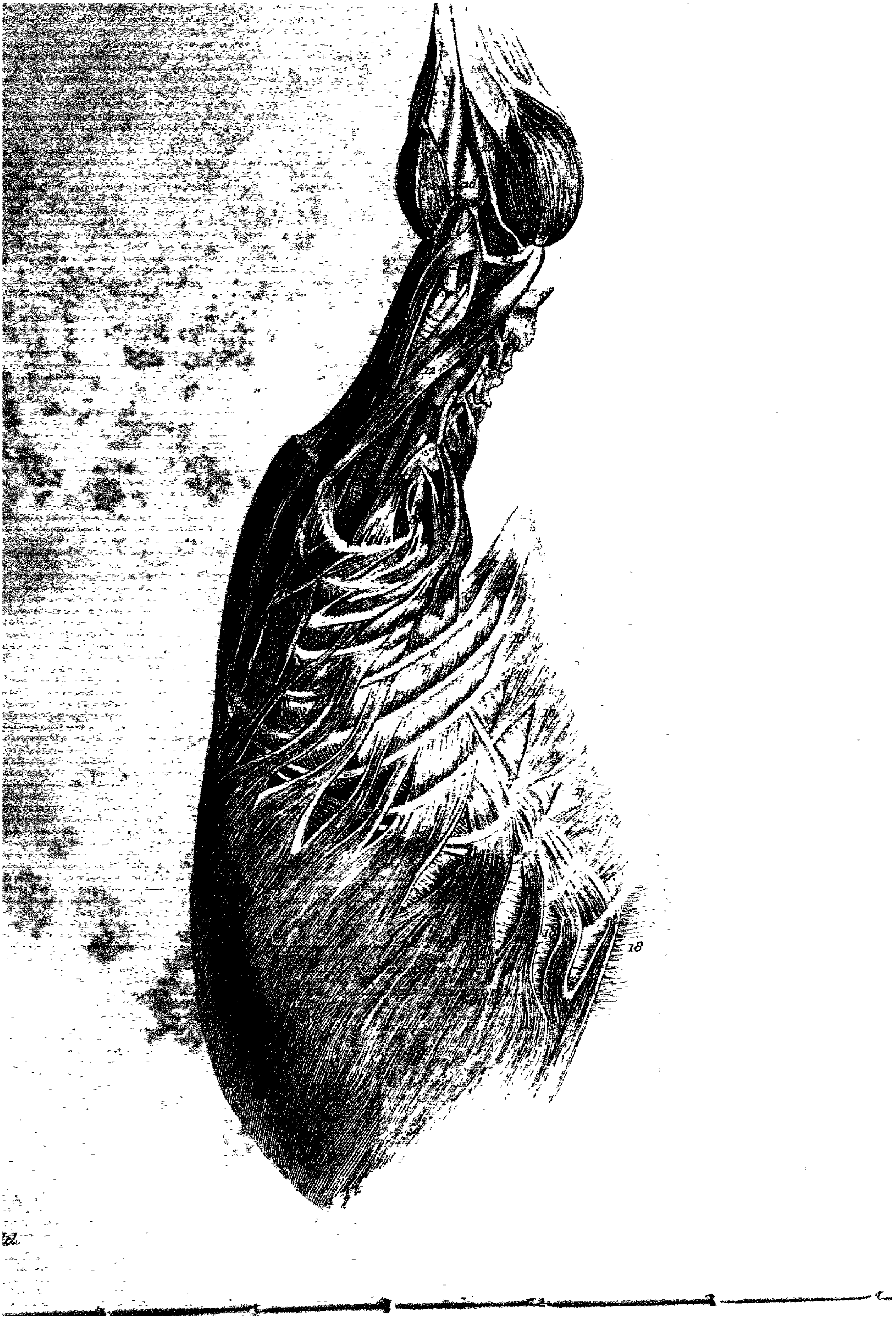


Fig. X.

Dog.




20
12
11
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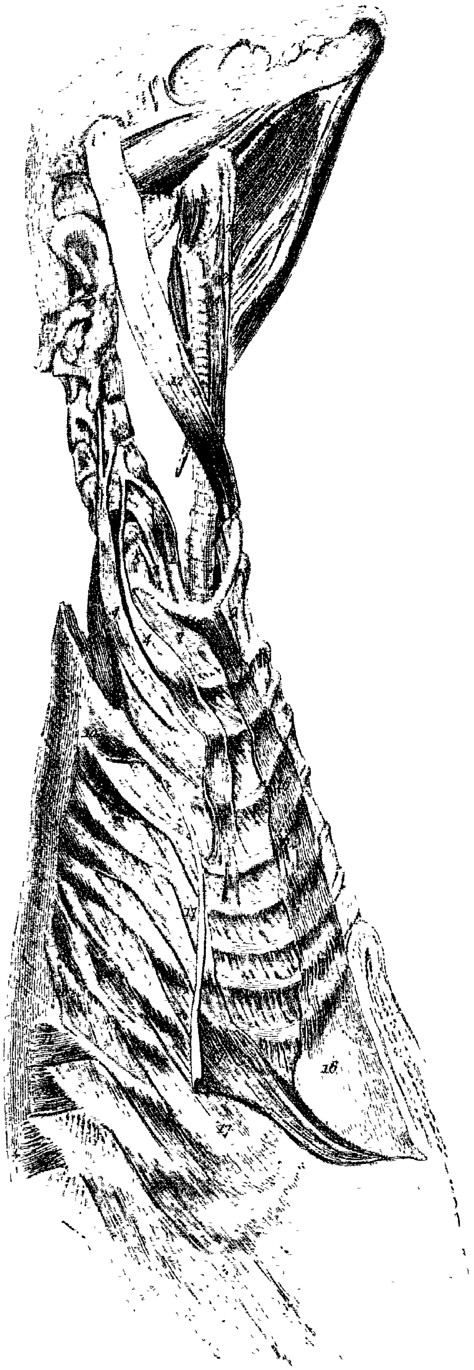
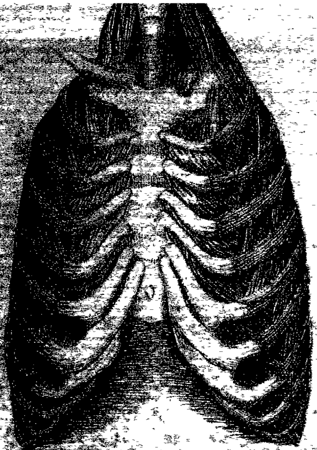
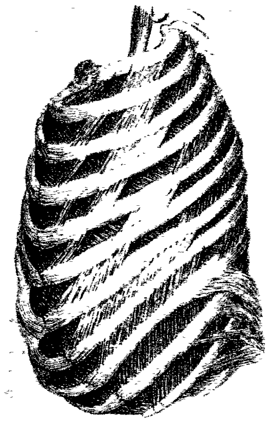
19
18

Fig. XII.
Otter.







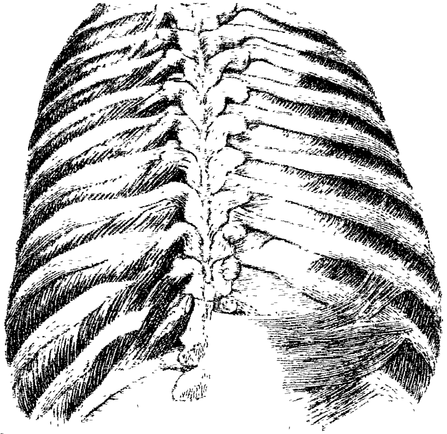
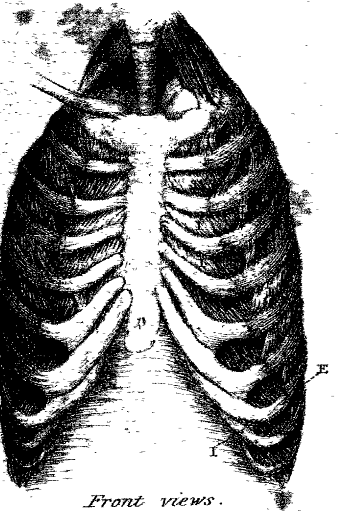


Fig. XIII b.

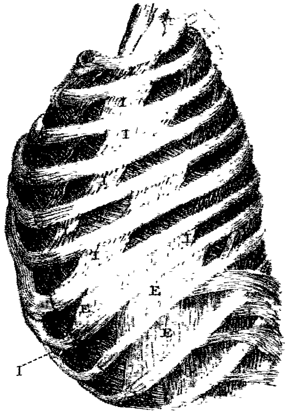
Fig. XIV b.

Fig. XV b.

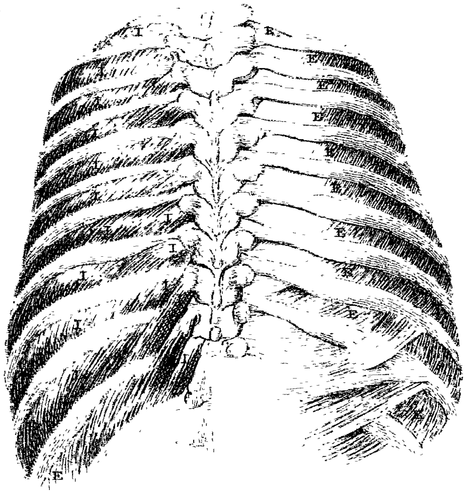
The Lungs distended as in Expiration.



Front views.



Side views.



Dorsal views

Position of the Ribs and action of the Intercostal muscles in Expiration and Inspiration.

At first sight the opposite action of the different fibres of the same muscle seems contradictory and unnatural, but when we find that the ribs at the upper part of the chest approach, whilst those of the lower part recede from each other, and that the posterior portion of each rib moves backwards, while the anterior portion moves forwards, we admire the perfect subservience of the actions of the muscles to the motions of the ribs. We now wonder that the motion of the different ribs, and of the same rib in different parts, should be so opposite; but when we find that the motions of these ribs and of the diaphragm exactly correspond to the form and capacity of the lungs in different animals, and that the form and capacity of the lungs are in each exactly fitted to the habits of the animal, we feel that we have some insight into the most beautifully adjusted and harmonious piece of machinery that either art or nature has constructed.

Description of the Plates.

The same figures denote the same parts in all the illustrations, both in the engraved figures and in the drawings deposited with the paper in the Archives of the Royal Society.

1. The Scalenus of the first rib, present in all, voluminous in the Porpoise (fig. VII.), trivial in the Seal (fig. VIII. §§ 10.23.47.58.71.72.82.83).

1 *a*. A scalenus of the first rib, peculiar to the Porpoise (fig. VII.), external to the large funnel-shaped scalenus (§§ 71.72).

1 *a*. In Man (fig. XIII. *b*.), a funnel-shaped scalenus of the first rib often exists, acting to expand the apex of the lung (fig. XXVI. Archives of the Royal Society) (§ 84).

2. A posterior scalenus of the first rib, present in the Otter, Calf and Rabbit (figs. XII. IX. XI.), and the Monkey (fig. XV. in the Archives of the Royal Society).

2 *a*. An additional insertion of No. 1. passes in the Calf (fig. IX.) to the second rib.

3. A posterior and external scalenus of the first rib, inserted near the head of the bone, external to the levator costæ, exists in the Calf and Dog (figs. IX. X.), and the Monkey and Ass (figs. XV. X. Archives of the Royal Society).

4. The long anterior scalenus to several ribs, exists in the Dog, Otter, Seal, Rabbit and Calf (figs. X. XII. VIII. XI. IX.), and in the Monkey (fig. XV. Archives of the Royal Society) (§§ 47.58).

5. The first levator costæ.

6. The levatores costarum (§§ 7.9.23.50.86).

7. The external intercostals (§§ 6.7.24.46.48.49.60.85).

7 *a*. In Birds (figs. III. VI.), portions of the external intercostals arise from the spine (§ [illegible]).

7^1. In the Chameleon (fig. II.) there are external intercostals, whose fibres are almost vertical, superficial to the usual external intercostals (§ 14).

7^1. In the Rabbit (fig XI.) a supracostal muscle passes from the seventh rib to the eighth, ninth and tenth ribs.

8.8 *a*. In the Porpoise (fig. VII.) a web of superficial fibres passes from the first and second to the third, fourth and fifth ribs (§ 74).

9. The portions of the internal intercostal muscles between the costal cartilages. In Birds (figs. III. VI.) the muscles between the sternal ribs are joined to those between the vertebral ribs (§§ 18.24). In the Porpoise and Calf (figs. VII. IX.), and the Monkey and Pig (figs. XV. VII. Archives of the Royal Society), the intercartilaginous portion of the internal intercostals are distinctly separated from the intercostal portions (§§ 48.49.61.85). In the Seal (fig. VII.) the first costal cartilage has a special elevator (§ 62).

9 *a*. 9 *b*. In Birds (figs. III. VI.) and in the Chameleon (fig. II.) triangular muscles arise from the sternum and are inserted into the sternal ribs (§§ 23.15).

10. The serratus posticus superior (§§ 52.64).

10 *a*. In the Seal (fig. VIII.) there is an intermediate serratus posticus (§ 64).

11. The serratus posticus inferior. In the Porpoise and Rabbit (figs. VII. XI.) the superior and inferior serrati are blended (§§ 53.64.65.75.88).

12. Sterno-mastoid (§§ 59.90).

13. Sterno-hyoid (§§ 59.71.90).

14. Sterno-thyroid (§§ 59.7.90).

15. In the Seal and Rabbit (figs. VIII. XI.) there is a depressor of the first rib arising from the sternum. In the Seal there are, in addition, depressors of the second and third ribs, which are indeed, with the depressor of the first rib, additional fasciculi of the external oblique (§ 67).

16. The rectus abdominis is inserted in the Otter and Rabbit (figs. XII. XI.) into the first rib (§ 67).

16 *a*. A depressor of the first rib, arising from the aponeurosis of the rectus, exists in the Dog and Calf (figs. X. IX.), and the Monkey and Ass (figs. XV. X. Archives of the Royal Society) (§§ 54.67).

17. External oblique (§§ 16.26).

17 *a*. In the Fowl (fig. III. *a*.) fibres of the external oblique arise from the sternum (§ 26).

18. The internal oblique (§§ 26.54.66.93).

19. Transversalis (§§ 11.16.26.54.60.73.94).

19 *a*. In the Fowl there are sterno-costal muscles to the 1st, 2nd and 3rd ribs (§ 26).

20. Sterno-costal muscles, or triangulares sterni (§§ 68.73.94).

The transversales and sterno-costals combine to form one muscle in the Mammalia (figs. XI. *b*. XII. *b*. XIII. *b*. XVI. *b*. XXVI. Archives of the Royal Society), and in a modified manner in the Fowl and Chameleon (figs. III. II.) (§§ 68.73.94).

21. The internal intercostals (§§ 48.49.61.85).

21^{1}. In the Chameleon and Snake (figs. II. I.) an infra-costal muscle passes from the upper edge of one rib to the rib but one above (§§ 11.16).

21 *a*. In the Hawk (fig. IV.) there is an infra-costal from the eighth to the sixth rib. In the Stormy Petrel (fig. V.) a muscle acts from the pelvis on the lowest rib.

22.23.24. Digastricus, and its varieties.

In the Monkey and Ass (figs. XV. X. Archives of the Royal Society) the digastricus is two-bellied, as it is in Man; it is replaced in the Seal and Rabbit (figs. VIII. XI.) by two muscles arising from the mastoid processes inserted, one into the hyoid bone, the other into the lower jaw; and in the Dog (fig. X.) by one muscle to the lower jaw. The Porpoise (fig. XVI. *b*. Archives of the Royal Society) has a powerful genio-hyoid in lieu of the digastricus.

27. In the Porpoise (fig. VII.) a muscle passes from the cervical vertebræ to the ribs, resembling a scalenus (§ 74).

28. Omo-hyoid in the Monkey (fig. XV. Archives of the Royal Society).

29. In the Fowl and Stormy Petrel (figs. III. *a*. IV.) a muscle acts from the superior ribs on the scapula to raise it (§ 25).

30. The sacro-lumbalis is shown in the Ass (fig. X. Archives of the Royal Society). In the Chameleon and Fowl (fig. II. III.) an analogous muscle arises from the pelvis to be inserted into the ribs (§§ 16.26.54.66.94).

30. In the Snake (fig. I.) represents a series of muscles that pass from rib to rib and serve as muscles of progression (§ 3).

31. In the Stormy Petrel (fig. V.),

31 and 32, in the Fowl (fig. III. *a*.), are muscles acting from the scapula to raise the ribs during inspiration (§ 25).

31. In the Snake and Chameleon (figs. I. *a.b.*, II.), are muscles acting from the dorsal vertebræ to lower the ribs (§§ 11.13.16).

32. In the Chameleon (fig. II. *b*. Archives of the Royal Society) are muscles acting from the vertebræ on the ribs to narrow the chest (§ 16).

32.34. In the Snake (fig. I. *b*.) are muscles acting from the vertebræ on the ribs to raise them (§ 10).

33. In the Snake is a muscle passing from rib to rib near their vertebral articulations (§ 10).

PLATE XXIII.

Figs. I. *a.b.* (figs. I. *c.d.e.* Archives of the Royal Society). The muscles of respiration in the Snake (§§ 3–11).

Fig. II. (figs. II. *b.c.d.* Archives of the Royal Society). The muscles of respiration in the Chameleon (§§ 12–16).

PLATE XXIV.

Figs. III. *a.b.c.* Muscles of respiration in the Fowl (§§ 17–27).

PLATE XXV.

Fig. IV. Muscles of respiration in the Hawk (§§ 17–27).

Fig. V. Muscles of respiration in the Stormy Petrel.

Fig. VI. *a.* Muscles of respiration and ribs of the Swan, as they are on expiration. The sternum is pushed as near as possible to the spine.

Fig. VI. *b.* Muscles of respiration and ribs of the Swan, as they are on inspiration. The sternum is drawn as far as possible from the spine.

These views demonstrate the external intercostals to be inspiratory; they are shortened in fig. VI. *b.*, and the internal intercostals to be expiratory. They are shortened in fig. VI. *a.* (§§ 22.25.26).

PLATE XXVI.

Fig. VII. (fig. XVI. *b.c.d.* Archives of the Royal Society). Muscles of respiration in the Porpoise (§§ 70–77).

Fig. VIII. (fig. XII. *b.* Archives of the Royal Society). Muscles of respiration in the Seal (§§ 55, &c. 62.67–69).

PLATE XXVII.

Fig. IX. (fig IX. *b.c.d.* Archives of the Royal Society). Muscles of respiration in the Calf (§§ 36, &c. 43).

Fig. X. (fig. XI. *b.c.d.* Archives of the Royal Society). Muscles of respiration in the Dog (§§ 55–69).

PLATE XXVIII.

Fig. XI. (fig. XII. *b.* Archives of the Royal Society). Muscles of respiration in the Rabbit (§§ 55, &c. 66.67).

Fig. XII. (fig. XIII. *b.* Archives of the Royal Society). Muscles of respiration in the Otter (§§ 55, &c. 67.68).

(Fig. X. *a.b.c.d.e.* Archives of the Royal Society). Muscles of respiration in the Ass (§§ 40–54).

(Fig. XV. *a.b.c.* Archives of the Royal Society). Muscles of respiration in the Monkey (§§ 55, &c. 78).

PLATE XXIX.

Illustrates the position of the ribs and the action of the external and internal intercostal muscles in expiration and inspiration in Man.

Fig. XIII. *a.b.* Are front views.
Fig. XIV. *a.b.* Side views; and
Fig. XV. *a.b.* Dorsal views in the young and the adult man.

In figs. XIII. *a.*, XIV. *a.*, XV. *a.*, the lungs are flaccid (expiration).

In figs. XIII. *b.*, XIV. *b.*, XV. *b.*, the lungs are distended (inspiration).

These views were taken by aid of a tracing frame (§ 4), and reduced by a pentagraph.

These figures demonstrate that during inspiration (§§ 1.4)

The five superior ribs, the thoracic set, approach each other.

The four inferior ribs, the diaphragmatic set, recede considerably from each other.

The sixth, seventh, and eighth ribs, the intermediate set, recede slightly from each other (§ 81).

The dorsal arch is deepened and shortened (§§ 80.81).

The external intercostals of the thoracic set of ribs are throughout inspiratory.

The external intercostals of the diaphragmatic set are, in front, expiratory; behind, inspiratory.

The external intercostals of the intermediate set are throughout inspiratory, being feebly so to the side (§ 85).

The eighth external intercostal is behind inspiratory; to the side, expiratory; and in front, acting from the fixed on the floating cartilage, inspiratory.

The internal intercostals are all expiratory behind.

The internal intercostals are inspiratory between the costal cartilages of the thoracic set of ribs.

The internal intercostals are inspiratory between the ribs of the thoracic set in front, where they approach each other during inspiration.

The internal intercostals between the diaphragmatic and intermediate sets of ribs, are throughout expiratory (§ 85).

The following additional drawings, illustrative of the paper, are deposited in the Archives of the Royal Society.

Fig. XIX. *a.b.* The female (§ 97),
Fig. XXI. *a.b.* and fig. XXII. *a.b.* The child (§ 99),
Fig. XXIII. *a.b.c.d.* The old man (§ 100),
Fig. XXIV. The fœtus, and

Fig. XXV. The new-born infant (§ 98), are figures of the chest in pairs, illustrating the position of the ribs and the action of the intercostals in expiration and in inspiration.

Fig. VII. *a.b.* The Pig,

Fig. VIII. *a.b.* The Sheep,

Fig. X. *a.b.* The Ass, and

Fig. XI. *c.d.e.f.* The Dog, are figures of the chest in pairs, illustrating the position of the ribs and the action of the intercostal muscles in expiration (the lungs being flaccid) and in inspiration (the lungs being distended) (§§ 31–49, 56–61).

Fig. XXVI. Shows the blending of the transversales and sterno-costals in Man to form one muscle (§ 94).

Fig. XXVI. *a.* The pleural scalenus (in Man) (§ 84) (fig. XIII. *b.* 1 *a*).

XXVII. *On the Physiology of the Human Voice.* *By* JOHN BISHOP, *Esq.*, *F.R.S.*

Received April 30,—Read June 11, 1846.

THE human voice is susceptible of several modifications, such as *timbre*, or quality, intensity, and pitch; including those successive transitions of tone from one pitch to another which constitute melody. The organs of voice comprise the thorax with the muscles of respiration, the lungs, trachea, larynx, pharynx, mouth, tongue, nasal cavities, nerves, and blood-vessels. Of these, the thorax and lungs may be considered an air-chest or bellows, the trachea a portevent or air-pipe, and the glottis a complex reed. The trachea varies in length and diameter with the age and sex of individuals, until they arrive at the adult period of life. By its structure the trachea is endowed with elasticity, together with the power of longitudinal extension and relaxation, and of increasing or diminishing in diameter: the acoustic effect of these properties will presently be investigated.

The sum of the diameters of the two bronchi is greater than that of the trachea; by which adaptation the latter is more readily supplied with air during the vocalization of the breath. In all Mammalia, Birds, and Reptiles, the axes of the bronchi are inclined to that of the trachea at a greater or less angle. With reference to the voice, the larynx is the most important organ in the whole apparatus. The mouth, fauces, tongue, and nasal organs are not necessary to the production of voice; nevertheless they exercise a considerable effect on its quality, and are indispensable for the production of articulate language. The thorax is sufficiently capacious to contain as much air after a full inspiration as will sustain the glottis in a state of vibration, when the tone is of moderate intensity, during the space of fifteen seconds, which will enable a person to pronounce in rapid succession from thirty to forty monosyllables at one expiration*.

The phenomena of the voice of animals must at a very early period have afforded to physiologists proof of the susceptibility of membranous structures to enter into a state of vibration; and it is now generally known that membranes, whether twisted into a cord like the string of a violin, or in the form of a parallelogram stretched in one direction as the vocal ligaments, or in that of discs stretched all round as the head of a drum, are all capable of producing musical sounds when properly excited.

The theory of the vibratory movements of stretched membranous surfaces has occupied the attention of many of the most celebrated mathematicians, such as

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* Having already described in the Cyclopædia of Anatomy and Physiology the minute anatomy of the larynx, the author considers it unnecessary to encumber this paper with details of that nature.

Euler, Bernoulli, Riccati, Biot, Poisson, Sir John Herschel and others. It is a subject requiring the most profound analysis, and the solution of problems of much greater complexity than those either of strings or bars, but in order to bring the theory of vibrating membranes within the reach of computation, the membranes are supposed to be homogeneous and of equal thickness and elasticity. Now these hypotheses will not satisfy the conditions of the vibratory movements of the vocal organs, such as the windpipe for example, which is composed of tissues of variable thickness, density, and elasticity; it would therefore be futile in the present state of the science of acoustics, to attempt any mathematical solution of the laws of the equilibrium and movements of the heterogeneous masses of the vocal tube. When, however, a membrane is stretched in one direction only, it obeys the same laws as a string.

Having adapted two laminas of India rubber to a pipe connected with the bellows of an organ, M. Biot caused a current of air to pass over their free edges, by which means he obtained sounds of different pitch with facility. The Rev. Mr. Willis made similar experiments with leather and caoutchouc, but with these substances could not produce so great a range of tones as the glottis will yield, and therefore concluded that the vocal ligaments possess greater elasticity. Mr. Willis has also investigated the position in which it is necessary that membranous laminas should be placed, in order that they may be excited and sustained in a state of vibration. He has likewise given a satisfactory explanation of the mode of action of the air on reeds, such as those of the organ pipe, which applies also to free reeds, and every other case where a vibratory motion is maintained by a current of air.

The experiments and theory of Mr. Willis are exceedingly important, for he has shown that in ordinary breathing the vocal cords remain inclined to each other, at an angle which prevents any vibratory motion; whereas when their surfaces lie in the same plane the breath immediately excites them into a state of vibration; the natural position of the vocal cords in these two states is seen in Plate XXX. figs. 1 and 2. Müller also made some experiments on stretched membranous bands, both isolated, and in connection with a tube, from which he concludes that the force of the current of air influences the *pitch* of the note produced, so that a strong current will produce a more acute tone than a weak one, and *vice versâ*; but the author has not found this to be the case in any of the experiments which he has made. To obtain a pure quality of tone when two membranous bands are stretched across a tube, it is necessary that they should be of equal weight and length, and subjected to equal tension, otherwise they cannot vibrate freely in equal periods of time. According to Cagniard la Tour, if two membranous laminas of equal length and weight be stretched by unequal forces, so that there is an interval of a fifth between the notes they yield separately, the note resulting from their combined action is the intervening third. Müller is disposed to doubt the accuracy of La Tour, but his own views do not differ materially from those of the latter, as he says that when one tongue is most readily thrown into vibrations by the current of air, the sound is emitted by it alone, but if the blast is such that it throws them both into motion, they may both vibrate together; and by reciprocation produce a simple sound intermediate between the fundamental note of the two vibrating separately; they may also emit two distinct sounds, or the blast being modified, the two sounds may be produced in succession. From these researches it appears, that membranous laminas, stretched in imitation of the thyro-arytenoid ligaments, will not only vibrate readily, but produce a range of musical tones. It has been remarked that sounds are most readily produced when the two laminas are stretched in the same plane, and that a smaller volume of air is required the nearer the edges of the laminas approach each other, and a still smaller one when their edges actually touch. De Kempelen states, that to produce sound, the edges of the glottis must be approximated to within $\frac{1}{12}$th, or at least $\frac{1}{10}$th of an inch. These experiments upon artificial vibrating tongues perfectly agree with those the author has made on the larynxes of animals. Owing to the nature of the articulation of the thyroid with the cricoid cartilage, and the manner in which the crico-thyroid muscles act, an equal tension of both the thyro-arytenoid ligaments is simultaneously secured, supposing the arytenoid cartilages to be at the same time in corresponding positions, which is a necessary condition for the production of a synchronous vibratory motion in the two lips of the glottis.

If the larynx of an animal is dissected out, and the vocal cords are stretched, they will vibrate like a piece of caoutchouc or leather in a current of air. In conducting these experiments, it is necessary to secure the same conditions as those which are required in the laminas above-mentioned; for instance, the inner edges of the glottis must be turned towards each other till they are in the same plane and parallel to one another, before they will produce any sound; hence we infer, that when the tension of the arytenoid ligaments takes place in the living animal, they turn upon their axes till their planes (which in the state of relaxation are inclined to the axis of the vocal tube) become perpendicular to it, and as the edges of the glottis approximate, and its chink is nearly or entirely closed up, they acquire the true vibrating position. The production of the most simple tones of voice requires the associated actions of a most extensive range of organs, and it is calculated that in the ordinary modulation of the voice, more than one hundred muscles are brought into action at the same time.

The lungs having been first supplied with air by the muscles of inspiration, and the air in the chest and trachea having subsequently been condensed by the muscles of expiration, a portion of the edges of the glottis yields to its pressure, and is curved upwards, so as to form an angle with the axis of the vocal tube, leaving between them a narrow aperture through which the air escapes. The tension and elasticity of the vocal ligaments tend to restore them to the plane of the vibrating position; the air having been rarefied below the glottis during their elevation, becomes condensed on their depression, and the necessary force is again accumulated to re-elevate the vocal ligaments. An oscillating movement, consisting of a partial opening and closing of the glottis, then takes place, which being communicated to the contiguous air, the sounds of the voice are produced.

The relative length of the vibrating edge of the glottis is regulated by the pressure of the column of air in the trachea, and the resistance of the vocal ligaments. The intensity of the voice in the same medium, and under similar collateral circumstances, depends on the pressure of the column of air in the trachea, and the range of motion performed by the vibrating edges of the glottis. The vocal ligaments do not vary the pitch of the voice by their tension alone, but by their variations in length and tension conjointly. The author has learnt this from his own experiments on the vocal functions of the larynx, which have been confirmed both by Majendie and Mayo; the former having observed in the larynx of a dog that a longer portion of the ligaments of the glottis vibrated during the utterance of grave tones, and that the length was diminished as the tones became acute. The latter had an opportunity of inspecting the movements of the glottis in a man who had made an attempt to destroy himself by cutting his throat. In this case the larynx was divided immediately above the vocal cords, and in consequence of the oblique direction of the wound, the arytenoid cartilage and the vocal cord on one side were injured. During respiration the glottis was observed to assume a triangular form, but when a sound was uttered, the chordæ vocales became nearly parallel, and the rima glottidis of a linear form. The posterior part of the aperture did not appear to be closed. In a second case of this kind, he observed that the arytenoid cartilages, as long as the vocalization of the breath continued, maintained the position which they had assumed when the glottis was closed entirely[*]. The vibrations of the thyro-arytenoid ligaments are considered by Ferrien[†] to be analogous to those of strings; hence he denominated these ligaments (though improperly) chordæ vocales. He imagined that the longitudinal tension of these cords alone governed the pitch of the voice. Mr. Willis[‡] has embraced the hypothesis of Ferrien; he observes, that to obtain the various notes of the glottis, it is only necessary to vary its longitudinal tension after the ligaments have been placed in the proper position; but M. Biot[§] remarks, "Qu'y a-t-il en effet dans la glotte qui ressemble à une corde vibrante? Comment pourroit-on en tirer jamais des sons d'un volume comparable à ceux que l'homme produit? Les plus simples notions d'acoustiques suffisent pour faire rejeter cette étrange opinion."

On inspecting the larynx from above, we see two very nearly rectangular-shaped laminas, one on each side the chink of the glottis, but nothing resembling an isolated cord. The mucous membrane which lines the thyro-arytenoid ligaments (to which it closely adheres), as well as the rest of the vocal tube, must be considered as forming a part of the weight of the vibrating surface upon which the air acts; the thyro-arytenoid ligaments confer on this membrane the requisite tension and resistance during vocalization, and it is this membrane which gives the sides of the glottis their laminated figure. The vocal ligaments, with their lining membrane, are stretched by the thyro-cricoid muscles, not all round like a drum, but in one direction only, namely, in that of their length, being attached on three sides, leaving one only free to vibrate. The vocal cords are, as has been seen, rectangular-shaped membranes, and from experiments made on the larynx after death by Ferrien, Müller, and others (which the author has repeatedly verified), are found to vibrate like cylindrical cords; we will therefore apply to the former, the well-known formulas which regulate the vibrations of the latter.

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[*] Mayo, Outlines of Physiology, p. 199.

[†] Mémoires de l'Académie.

[‡] Cambridge Philosophical Transactions, vol. iv.

[§] Précis, Elem. de Phys. tom. i. 398.

In cords composed of the same material, and of uniform thickness, the time of a complete musical vibration, or *double* oscillation, is

$$t=2\sqrt{\frac{lp}{2gP}}, \quad \ldots\ldots\ldots\ldots \quad (1.)$$

where l is the length of the cord, p its weight, P the force with which it is stretched, and $g=16\frac{1}{12}$ feet.

In order to apply this formula to the vocal ligaments, let a be their depth, b their breadth, and δ their specific gravity; then p will be equal to $abl\delta$, and equation (1.) becomes

$$t=2l\sqrt{\frac{ab\delta}{2gP}}; \quad \ldots\ldots\ldots\ldots \quad (2.)$$

and the number of such vibrations in 1″ will be

$$N=\frac{\sqrt{2gP}}{2l\sqrt{ab\delta}}. \quad \ldots\ldots\ldots\ldots \quad (3.)$$

We observe in the first place, that if all other things remain the same, the number of vibrations varies inversely as the length of the cord; hence, if the vocal ligaments were divided by nodes into n ventral segments, each segment might be considered a separate vibrating ligament, whose length would be $\frac{1}{n}$th of the vocal cord, and consequently the number of its vibrations in a given time would be n times as many as that of the whole cord.

Owing to the elasticity of the thyro-arytenoid ligaments, their lengths, when in a state of repose, differ considerably from those which they present under the greatest tension. They differ also in the two sexes. In a series of experiments by Müller, the differences of length were observed to be as represented in the following table, the figures of which are in inches and decimals of an inch. From these experiments it appears that the lengths of the male and female vocal cords in repose are nearly as 7 to 5, and in tension as 3 to 2. In boys at the age of fourteen, the length is to that of females after puberty as 6·25 to 7, so that the pitch of the voice is nearly the same. These experiments afford an idea, although an imperfect one, of the elasticity of the vocal ligaments. It has always been a subject of surprise, if the thyro-arytenoid ligaments obey the laws of strings, how such short and narrow laminas should produce such very grave tones as many bass singers are capable of uttering; and this struck M. Biot as one of the circumstances which in his opinion prove their mode of vibration to be unlike that of strings. He asks, "Où pourroit-on trouver la place nécessaire pour donner à cette corde la longueur qu'exigent les sons les plus graves ?"

Subjects of experiment.	No. of experiments.					
	1.	2.	3.	4.	5.	6.
Male in a state of repose	0·7087	0·63	0·63	0·83	0·748	0·748
Male in the state of greatest tension...	0·83	0·83	0·984	1·0236	0·9055	0·9055
Female in a state of repose	0·47244	0·47244	0·551	Boy of 14 in repose. 0·414		
Female in the state of greatest tension	0·63	0·59	0·63	Boy of 14 greatest tension. 0·571		
Mean length in male	In repose. 0·72834	Greatest tension. 0·912070				
Mean length in female	0·49868	0·61679				

The author is acquainted with some bass singers who can produce the note C which results from sixty-four musical vibrations. Let us now investigate this phenomenon more closely, and endeavour to explain how such grave tones are produced by such extremely short membranes. Müller has contrived several ingenious pieces of mechanism, seen in Plates XXXI. and XXXII., by means of which he was enabled to estimate the amount of tension, lateral compression, and atmospheric pressure on the vocal cords, during the production of sound. In order to find the variations in the amount of condensation of air in the vocal organs in the production of sounds differing in pitch and intensity, the apparatus was furnished with a manometer, Plate XXXI. fig. 3. *v*. From that portion of the experiment which was confined to the investigation of the effects produced by tension of the vocal, compared with that of musical cords, he obtained results which are comprised in the following table.

No. of experiments.	Weights employed.		
	4 loths*.	16 loths.	64 loths.
1	C^1	A^1	$G^2\sharp$
2	$C^1\sharp$	B^1	$A^2\sharp$, A^2
3	$G^1\sharp$	$C^2\sharp$	C^3
4	A^1	D^2	C^3
5	$A\sharp$	$F^1\sharp$	G^2
6	$A\sharp$	$G^1\sharp$	G^3
7	D^1	C^2	A^2
8	$D^1\sharp$	B^1	A^2
9	G	G^1	G^2 both octaves imperfect.

The notes of the different octaves from C to C are distinguished in the above table by ciphers, the C^1 answering to 256 vibrations; the notes below C have no cipher. Müller states that the numbers of vibrations in these experiments are not exactly in direct ratio of the square roots of the stretching forces, and that the weights 4, 16, 64 did not produce the octaves, but generally from a semitone to two or three tones lower. Now this result should have been anticipated; but it does not seem to have occurred to him that whilst he increased the tension he at the same time increased the length, and we know (eq. 3.) that the number of vibrations in this case varies as $\frac{\sqrt{\text{tension}}}{\sqrt{\text{length of cord}}}$, and consequently the numbers actually produced by the weights above-mentioned, ought (agreeably to Müller's experiments) to be less than those which correspond with octaves. We see by the first experiment in the above table that the tension sufficient to produce 818 musical vibrations is 64 loths, or very nearly 33 ozs. If, therefore, we take the mean length of the vocal ligaments under the greatest tension at ·91 of an inch, and substitute in equation (3.) their values for all known quantities, remembering that P represents the tension of one vocal cord, we shall find the weight of each ligament, viz.

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* A loth = 225·5531 grs. English.

$$abl\delta = \frac{g\,\mathrm{P}}{2l\,\mathrm{N}^2} = 1\cdot144 \text{ grs.} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (4.)$$

In an adult male I found that the two vocal ligaments, when divested of mucous membrane, weigh one grain, which is scarcely one-half their weight by theory; hence it appears that a considerable portion of mucous membrane is connected with the vocal cord in the production of sound, which agrees with the anatomy of these parts.

It is now necessary to offer some explanation respecting the vital state of the vocal ligaments. The state of repose is the ordinary condition of the vocal ligament in the living subject, when the voice is not exercised; but we must not therefore conclude it to be incapable of further contraction. In fact, the state of repose during life is a state of tension, for the ligaments being connected with the thyro-arytenoid muscles, not in a few points, but continuously throughout their whole length, must obey the motions of these muscles, which, like all muscles, are in a state of tension during repose. We also know by experience that when we produce a sound lower than the usual pitch of our voice, the crico-thyroid chink is opened principally by the contraction of the same muscles, and the ligaments must therefore at the same time be relaxed. It appears, then, both from the anatomy and physiology of the human larynx, that the ordinary state of the vocal cords is one of considerable tension, which admits of being lessened, and thereby produces the range of lower notes. If we suppose the glottis to be partially closed when we are talking, that is at the ordinary pitch of our voice, and to be more opened as the tones become graver, this of course will cooperate with the relaxation of the vocal cords. In the production of the higher notes the crico-thyroid chink closes, and the thyro-arytenoid muscles, and consequently the ligaments are elongated. Since, therefore, the vocal ligaments have been proved to extend and contract for acute and grave tones respectively, and after death vibrate in a great measure like musical strings, we think it may be fairly inferred that they likewise obey, to a certain extent, during life the laws of the vibrations of such strings, and that the conclusions which we have derived from the foregoing formulas are not far removed from the truth. A further confirmation of these views may be derived from the following considerations. The length of a cord of invariable weight varies directly as the tension, and inversely as the square of the number of vibrations. Now, if we assume the length of the vocal cord, which gave $G^2\sharp$ under a tension of 32 loths to be ·91 inch, which is the mean length of the male vocal cord in its greatest tension, according to the first table, and which gave the notes A^1, C^1 under the tension 8 and 2 loths respectively, the corresponding lengths of that cord, according to the formula, will be ·83 inch and ·58 inch*; but ·58 inch is less than the least length in repose in the table. This result is, however, quite consistent with the theory here proposed; because after death the thyro-arytenoid muscle becomes of itself elongated, and consequently the vocal ligament attached to it, and therefore the length of the ligament must be greater in this state than when it is in that which we have defined to be the state of repose before it has lost its vitality.

In experiments made on the larynx by stretching the vocal ligaments with given weights, and by forcing a current of air through the glottis, care must be taken to keep the organs moist, and of the same temperature which they possess during life. The amount of condensation of the air in the vocal tube has been ascertained by CAGNIARD LA TOUR, and MÜLLER, the former in the living, and the latter in the dead subject. In a person who had an opening in the windpipe after the operation of bronchotomy, CAGNIARD LA TOUR found that the tension of the air in the vocal tube, whilst blowing the clarionet, was equal to a column of water of thirty centimetres in height, and that to produce a simple vocal sound in the same person, a tension of sixteen centimetres was necessary. MÜLLER found that he could produce sound in a larynx artificially by a tension of 3·4 centimetres, but for very loud sounds an increased tension was requisite. The discrepancy between the experiments of LA TOUR and MÜLLER may be ascribed to the circumstance that the one operated on the living vocal organs, but in a state of disease, the other on the organs after death.

Variations in the hygrometric and thermometric states of the air exert very powerful influence on the pitch of the voice; during the prevalence of a cold moist state of the atmosphere, especially in England, the voices of singers become lower by two or three notes, and regain their usual pitch when the air becomes dry†. In thus tracing

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[*] N varies as $\frac{\sqrt{P}}{\sqrt{l}}$ ∴ l varies as $\frac{P}{N^2}$, then ·91 inch : length of cord for A^1 : : $\frac{32}{(818)^2} : \frac{8}{(427)^2}$, the length of the cord for A^1 = ·83 inch; and the length for C^1 = ·58 inch.

[†] When GRASSINI came to this country, owing to the change from the air of Italy to that of England, her voice became one octave lower; after singing for two or three seasons, her natural voice returned, but it had lost its attractions with the low tones which had obtained her the greatest applause.—Trans. Lond. Med. Society, New Series, vol. i. 1846; Art. Aphonia, p. 36.

out the analogy between the laws of stretched cords and those of the vocal ligaments, it is not intended that those ligaments should be considered as stringed instruments, but only that this analogy is accurate so far as relates to the velocity with which an impulse is propagated along them. Dodart supposed the tension of the vocal cords to be merely subservient to an alteration in the size of the aperture of the glottis, and that the difference of $\frac{1}{54}$th of a fibre of silk, or $\frac{1}{384}$th of a hair in the dimensions of that aperture, was sufficient to alter the pitch of the voice; but this has been so completely refuted by more recent physiologists, and is so directly at variance with acoustic principles, that we need not give illustrations of its fallacy. M. Savart considered that the action of the air in its passage through the ventricles of the larynx, between the superior and inferior ligaments, is really the source of sound, and analogous to the mechanism of the bird-call or dog-whistle*. There is certainly a great resemblance in the structure of that instrument to the space above-mentioned in many of the higher animals, which might easily have led to this ingenious hypothesis; but, as we find neither superior ligaments nor ventricles of Morgagni in many of the order Ruminantia, in which the voice is very sonorous, this theory (as Müller remarks) is untenable.

We next come to the consideration of the alleged analogy between the action of the vocal ligaments and that of the reeds of musical instruments. This opinion is maintained by MM. Biot, Cagniard la Tour, Majendie, Malgaigne, Müller and several other distinguished scientific men. It is opposed principally by M. Savart, who observes that the *essential* principle of the action of reeds consists in the periodical opening and shutting of the orifice through which the stream of air passes, but that this is wanting in the glottis; and that were the latter a reed, the edges of the thyro-arytenoid ligaments which form the sides of the chink would be alternately forced asunder by the column of air in the larynx, and brought together by their tension; whereas, he found by experiment, that air blown through the glottis produced sound although its edges were from one-sixth to one-fourth of an inch asunder. M. Savart has however clearly mistaken the circumstance wherein the *essential* principle of reeds consists, since those of the clarionet, bassoon, hautbois, &c. do not entirely close the apertures through which the breath passes; and this is likewise the case with the natural reed formed by the lips of players on the flute and horn. There is in all probability a double action of the vocal cords in the production of sound; the one being a vibratory motion throughout their length similar to that of a musical string, and the other an oscillation like that of a reed, forming a partial opening and closing of the glottis. The author is led to adopt this view of the functions of the vocal organs from considering that every circumstance which he has established in his previous investigation of their action when treated as cords, is perfectly consistent with the hypothesis of their vibrating like the tongues of reeds; for let us now suppose them to be simply membranous tongues. In this case the axis of motion is the edge of the ligament attached to the thyro-arytenoid muscle; the vibrations take place in a plane perpendicular to the axis of that muscle, and the *length* of the tongue is the *breadth* of the ligament. The author has observed in repeated experiments on the larynx after death, that the chink of the glottis was partially opened and closed in the production of sound, and Müller found that by decreasing the breadth of the ligament he rendered the note more acute; but as this breadth is so small, being in its ordinary state in an adult generally less than one-tenth of an inch, it is extremely difficult to measure the variations corresponding with different notes; and the author cannot learn that any one has yet succeeded in determining these varying lengths with sufficient accuracy to form data for the application of the mathematical formulas of elastic vibrating tongues*. We know that the number of vibrations made by the same tongue in a given time varies inversely as the square of its length. If, therefore, a tongue whose length is only ·1 inch give any note, the length necessary to produce the octave will be ·07 inch, that is, the variation will be only ·03 inch; we see then how minute must be the changes answering to the intermediate notes, and consequently how much more difficult it is to determine them in the vocal ligament when considered as a tongue, than as a stretched membrane or cord. It is moreover observable that the extension and relaxation of the vocal cord, which, as we have seen, are analogous to those of a musical string, produce a corresponding shortening and elongation of its axis, regarded as a tongue; and lastly, since one tone only is produced at a time, the vibrations resulting from the double action which appears to exist in the vocal apparatus must be synchronous.

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* See Plate XXX. fig. 1′, *g*.

We have seen how nearly, when we take into account the delicacy and difficulty of the experiments, their results agree with the theory that the vocal cords are subject to the same laws as other stretched laminas, and it would be highly interesting to compare these results with the simultaneous variations which they undergo transversely, and thus discover how far the laws of vibrating elastic tongues may be applied to them. It might possibly be objected to the idea of this twofold action, that the production of sound by the vocal cords is sufficiently accounted for by supposing them to vibrate merely as elastic tongues, but then it is found by experiment, that by artificially dividing their length into two ventral segments, there results the octave of the fundamental note, which proves that at all events they vibrate as cords. In conclusion, we must ever bear in mind the vast difference between natural and artificial mechanism, and however complicated a problem it may be to determine that constitution of the vocal apparatus, by which the thyro-arytenoid ligaments may simultaneously obey the laws of cords and tongues, yet to a physiologist who is accustomed to meet with the most admirable contrivances and combinations in the animal frame, the difficulty of finding a strictly mathematical solution is, in such a case, no objection to its truth, when the facts, so far as they have been observed, are decidedly favourable to its reality. Were the movements of the glottis independent of any tube or column of air, the study of the functions of the vocal organs would be much more simple, but we find it situated nearly in the centre of the vocal tube of which the trachea and bronchi are the inferior, and the upper part of the larynx, pharynx, nose and mouth, the superior portion; we have therefore to consider the influence of this tube, and of its inclosed column of air in the production of voice.

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* The formula of Giordano Riccati is $N=\frac{n^2 D}{L^2}\sqrt{\frac{2gR}{G}}$, where N is the number of vibrations, D the thickness, and L the length of the tongue or rod, R its rigidity, G its specific gravity, *g* the space through which a body falls by gravity in 1″, and *n* a number constant, for each mode of vibration, depending on the number of nodes.

In order to investigate the mutual relations between a reed and a pipe, two methods may be adopted: one of these is to vary the pitch of the reed while the length of the pipe remains constant, and the other, to vary the length of the pipe with a reed sounding one tone only, when detached from the tube. In the construction of reeded pipes for musical purposes, it is incumbent on the mechanician to adjust the length of the tube to the pitch of the reed. When a free reed is used on the principle of Kratzenstein or Grenié, it is found that, if the pipe be not in perfect unison with the reed, the purity of the tone decreases within certain limits, as the discordance between the reed and pipe increases. The researches of MM. Biot, Weber, Willis and Müller, have greatly enlarged our knowledge on this subject. We learn from their experiments how great an influence is mutually exerted between a pipe and its reed, when the pitch of the one is made to vary whilst the other remains constant, and we may conclude that analogous effects are produced between the vocal tube and the glottis. The slightest knowledge of acoustics is sufficient to inform us that the pitch of any pipe, such as the organ, the flute, the trumpet, in short of all musical tubes vibrating in a similar manner, depends on the velocity of an impulse propagated in the air within, and is determined by the length of the pipe. So long as the tubes of musical instruments remain rigid, the nature of the materials which compose them, does not affect the pitch of the sound, but merely influences the quality of the tone, and it is indifferent whether we employ metal, wood, or paper in their construction; each of these substances will yield a tone of a particular *timbre*, or quality, depending on the nature of the motions produced among its particles by the friction of the air on its surface; but the pitch will be the same in each, if the lengths of the pipes be equal, proving that the air itself is the source of sound. When however the sides of the tube are composed of flexible membranes, the inclosed air has a vibratory motion, conjointly with, and subordinate to that of the parietes of the tube, whereby the pitch of the sound is affected, as well as its quality. M. Savart found that by taking tubes composed of layers of paper of constant length, but varying in thickness, graver sounds were produced as the parietes became thinner, and that the gravity of the sound was increased by moistening and relaxing the sides of the tubes. We shall presently see the application of these facts to the vocal apparatus.

We find the flexibility of the trachea and bronchi capable of being varied by the operation of two forces, the one longitudinal or parallel to the axis of the tube, the other transverse. The first of these comprises the muscles which elevate and depress the larynx; the latter, the cartilaginous segments of rings perpendicular to the axis of the tube having muscular fibres attached to their posterior extremities, the contraction and elongation of which regulate the diameter of the trachea. The pharynx, mouth and nasal cavities, which form the superior extremity of the vocal tube, are also provided with muscles to modify the tension of that part of the tube so that it may vibrate synchronously with the rest. The necessity for this change in the dimensions of the tube, in order that it may vibrate in unison with the glottis, is in accordance, not only with the joint system of pipe and reed above described, but also with what actually takes place in the vocal organs of living animals. When the voice is raised in the scale from grave to acute, a corresponding elevation takes place in the larynx towards the base of the cranium. By placing the finger on the pomum Adami this motion can be easily felt, and at the same time the thyroid cartilage is drawn up within the os-hyoides, and presses on the epiglottis; the small space between the thyroid and cricoid closes, the pharynx is contracted, the velum palati is depressed and curved forward, and the tonsils approach each other: the reverse of these phenomena takes place during the descent of the voice. These are the principal phenomena common to most Mammalia which can be recognised by external observation, the other changes being, on account of their situation, invisible.

The effects of these variations on the tone of the voice have been hitherto little understood. It has always appeared incomprehensible why the vocal tube should apparently increase in length in the production of the acute tones, and shorten in the grave; a circumstance which theoretically presents an acoustic paradox. DODART and many others have conceived the elevation of the larynx to be merely for the purpose of shortening the vocal tube in the supra-laryngeal cavity, and have considered the trachea as producing no effect on the pitch of the tone. M. MAJENDIE has also pointed out the shortening of this part of the tube. In order to ascertain the effect of these changes, the following experiments were made on the dead body. Having laid bare the vocal organs of an adult male, I raised the larynx to the position it would occupy by the elevation of the voice to an octave, being about half an inch, and at the same time minutely observed the position of the lowest ring of the trachea in reference to the sternum. By this operation I found the trachea was raised out of the chest, nearly to the same extent as the larynx had been elevated towards the base of the skull. The next step was to examine whether any change had taken place in the diameter of the tube. For this purpose, having measured the diameter of the trachea in its natural position, the larynx was again elevated to the same extent as before, when the diameter was found diminished one-third. These experiments prove that, contrary to the general preconception, the elevation of the larynx *shortens* the tube independently of the contraction between the thyroid cartilage and os-hyoides, and at the same time lessens its diameter. The same effects may easily be detected during life by placing the finger on the trachea immediately above the sternum during the elevation of the larynx, when the trachea is found to ascend out of the chest, and afterwards to return to its former position; a movement in which the lungs and bronchi participate. The alteration of the tube in diameter may also be perceived by grasping the trachea with the finger and thumb during the elevation and depression of the larynx[*]. These movements are so striking as to lead irresistibly to the conclusion, that there exists a constant adaptation between the tension and the vibrating length of the thyro-arytenoid ligaments and the walls of the vocal tube, in the production of tones of the ordinary register; for we have seen that the variations of the vocal cords, at least so far as relates to the modulation of sound, are perfectly independent of the length of the vocal tube, and consequently the changes in its length which we have just described are not at all *necessary* for that purpose. Again, the vocal tube is so short, that, as has been ascertained by WEBER and others, it could not, were it rigid, affect the pitch of the note produced by the glottis. As however this tube is composed of flexible materials, its effects are similar to those observed in M. SAVART's experiments; that is, the relaxed state of the parietes compensates for its want of length, and enables it to vibrate synchronously, and therefore to give forth sounds equally grave with those of the glottis, thereby reinforcing the tone which would indeed be produced, though with much less intensity, without this aid.

The falsetto, or *voce di testa*, has always been considered a most embarrassing subject of research, and its peculiar quality has excited the attention both of the physiologist and of the musician. Its most remarkable characteristic consists in its being less reedy in tone, and partaking nearly of the quality of the harmonic sounds of stringed and wind instruments. The change produced in the voice when passing from the falsetto into the common tone, or the reverse, is in some persons very sensible to the ear, whilst in others it is almost imperceptible. Some individuals, moreover, have the faculty of producing in the same pitch as many as eight or ten tones, possessing either the falsetto or the common character. The falsetto has been generally ascribed to some particular adaptation of the upper ligaments of the larynx. DODART[†] has attempted to prove that it is a supra-laryngeal function, and that the nose becomes the principal tube of sound instead of the cavity of the mouth. BENNATI[‡] also considered these tones to be modulated by the supra-laryngeal cavity alone. This hypothesis however is untenable, since it supposes the column of air not to be influenced by the trachea, which is contrary to experience. In order to detect some of the movements of the larynx while the voice is passing from the first to the second, or falsetto register, it is only necessary to place the point of the finger in the crico-thyroid chink, when it is found that at the moment the transition from the primary to the secondary register takes place, this chink, which was closed during the production of the highest note of the ordinary register, suddenly opens on the production of the first note of the falsetto register, and consequently the thyro-arytenoid ligaments are relaxed at the same moment the larynx falls, and the vocal tube is lengthened, although during these changes *the tones become more acute.* As soon as this has taken place, the larynx again rises as the voice becomes more acute. In a mezzo soprano voice endowed with a double falsetto, or third register consisting of several tones of each register, with the power of producing tones of the same pitch either of the ordinary or the falsetto quality, we observed that the larynx fell at the commencement of each register, and that the thyro-arytenoid ligaments were twice relaxed, but in a much smaller degree. These observations have since been verified by many musical persons.

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[*] Essays by the author in the London and Edinburgh Philosophical Magazine, for September, October and November, 1836.

[†] Mém. de l'Acad. 1707.

[‡] Recherches sur le Méchanisme de la voix humaine.

In order to explain the phenomena as connected with the production of falsetto tones, we must remember that at the highest note of the primary register, the crico-thyroid muscles are contracted as much as possible in closing the crico-thyroid chink, and therefore that no further tension of the vocal cords can take place. In this state of things the thyro-arytenoid muscles are at their maximum of elongation, and their transverse section is a minimum, consequently neither can a higher note be produced by an extension of the ligaments, nor are these muscles in a condition to affect the dimensions of the glottis; hence the necessity of some alteration in the state of the larynx in order to effect the scale of the falsetto, which is an octave above the ordinary register, and to prevent the mere repetition of the same series of sounds. This alteration might be produced in two ways; one of these is a partial closing of the aperture of the glottis caused by the action of the thyro-arytenoid muscles when they have returned to their ordinary condition, and are in a favourable state to produce that effect under the influence of the laryngeal nerves. For, let us suppose the larynx to be in the same state as at the commencement of the primary register, except that the chink of the glottis is half-closed; the consequence will be that as only half the length of the ligaments can be made to vibrate, the *octave* of the lowest note in that register will result from the same tension which produced that note, and this will manifestly be repeated in consecutive notes of the range of the falsetto. This range is limited in general to a few notes, owing probably to the chink being soon completely closed by the stretching of the vocal cords. It is also owing to this partial closing of the glottis that a much less quantity of air is required for the falsetto than for the ordinary scale, which is proved by our being able to sustain a given note in the falsetto a much longer time than we can sustain the corresponding note in the primary register. The partial closing of the glottis was observed by Majendie in his experiments on the dog, and by Mayo in the human subject. Another explanation was suggested by Gottfried Weber, namely, that the falsetto range is caused by a nodal division of the vocal cords producing harmonics of the fundamental notes, by which means the glottis acquires the same pitch as if it were half-closed. If we consider the glottis as a reed, it is evident that since the number of vibrations must in this case be the same for the same note as when we suppose the ligaments to obey the laws of cords, the axis of vibration or the *breadth* of the ligament must be duly diminished, which may be brought about by the rotation of the thyro-arytenoid muscle on its axis.

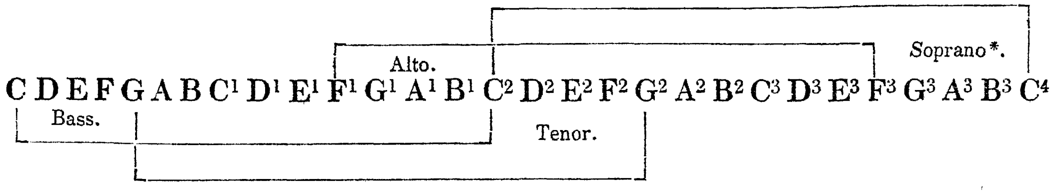
Having thus considered how the glottis may act in the falsetto range, let us now examine in what way the vocal tube contributes to its formation. We have seen that this tube gradually shortens during the ascent of the primary register, suddenly falls to its original length when the falsetto commences, and again diminishes during the secondary register. Now it appears from SAVART's experiments that, notwithstanding the shortness of this tube, the wave length of a column of air vibrating within it is the same as that of a rigid pipe of much greater length, and we have therefore strong grounds for believing that the notes of the primary register are reinforced in consequence of the vibrations of the glottis being always in unison with the fundamental pitch of the walls of the tube; hence in the falsetto, when the vocal apparatus has resumed its original condition, there will be less reinforcement of the sound, since the parietes of the vocal pipe are no longer in unison with the glottis, but give its grave octaves. We have found, by numerous experiments, that a flexible disc will vibrate to almost any pitch, but will reinforce the sound in a trifling degree only, unless the pitch be in unison with its fundamental note; and on the same principle we may suppose the intensity of the notes in the second register to be diminished, and their quality to be modified by the forced vibration of the walls of the tube, whilst in the primary, all things concur in augmenting the effects produced by the glottis. MÜLLER agrees with LEHFELDT in opinion, that the falsetto notes are produced by the vibrations of the inner portion of the borders of the vocal ligaments, and the variation of the pitch by their tension; and, although he does not mention by what mechanism this is effected, he seems to attribute it chiefly to the agency of the thyro-arytenoid muscles. The author's explanation is in many points coincident with that of MÜLLER, but he has taken into account one or two circumstances which appear to have escaped MÜLLER's attention. The natural key or pitch of the vocal organs may be found by sounding the voice, without either elevating or depressing the larynx. The grave octave of that note will be the fundamental sound of the vocal ligaments vibrating in their most relaxed state, with the glottis entirely open. Any tones of a graver pitch, produced by an unusually relaxed state of the vocal cords, lose both their quality and intensity, and cannot be included in the compass natural to the voice. According to the preceding principles, the pitch of the voice being usually an octave, or a fifth graver than the length of a column of air within the vocal pipe, we see the cause why a falsetto quality of sound cannot be obtained except during the production of acute tones. In many persons the speaking pitch is an entire octave graver than corresponds to the length of a tube, which would enable a column of air to produce the same sound; and in such persons the falsetto can seldom be effected. In consequence of the pitch of the vocal organs thus occupying a middle or central position between the acute and grave notes, a great facility is afforded to their action in modulating the voice. The vocal tube, like any other tube open at both ends, is said to be capable of producing the harmonics of its fundamental tone in the ratio of the series of natural numbers, 1, 2, 3, 4. These harmonic sounds have been described by Knecht of Leipsic, and by Dr. Young. I have occasionally thought that I have heard them during the forcible expiration which attends the boisterous laughter of children. The density of the air inspired is said to affect the pitch of the voice as in rigid tubes.

The influence of the epiglottis on the voice has been the subject of divers hypotheses. MM. Biot, Majendie, and Mayo have inferred from the experiments of Grenié, that the epiglottis prevents the tones from becoming more acute when they increase in intensity. Liscovius, on the other hand, states that neither its depression, elevation, nor even its entire removal has any effect on the voice*. Haller appears to have deduced the same opinion from the circumstance of birds being destitute of this organ. "Epiglottis equidem nihil facit ad vocem, cum ea (vox) nata sit et perfecta quamprimum aer ex glottidis rima prodit, et absque epiglottide aves suavissime canant." According to Müller, the influence of this organ on the pitch of the voice is exercised during its depression only, rendering the tones graver, and at the same time duller. He thinks we evidently employ it in this way during the production of very deep tones; and observes that, by introducing the finger at the side of the mouth, the epiglottis will be found to maintain the same position during the utterance of musical notes, whether they be of the falsetto character, or of the ordinary scale. I am disposed to ascribe to the functions of the epiglottis much the same value as Müller; since it is clear that its presence is not essential to the mere formation of voice, for it may be removed, together with the superior ligaments of the glottis, the ventricles of the larynx, and the capitula laryngis of Santorini, without impeding the vibratory movements of the glottis.

The art of singing consists in the application of the vocal organs to produce a certain succession of tones in some determinate order, which constitutes melody. This can be accomplished with precision by those only who can accurately discern with the ear, and imitate with the voice, the variations of a musical instrument, or other sounding body. In many persons the perception of sound is defective; so that, whatever may be the purity and intensity of their notes as single unconnected musical sounds, they can never be used for musical purposes, that is, for sounds succeeding each other at regular intervals, governed by fixed rules. Many persons can imitate the voices of birds and beasts, and diversify the character of their tones to an indefinite extent. These performances illustrate the perfection of the human voice, but the artifices by which they are effected have no reference to the subject under investigation. The musical varieties of the human voice are classed according to their *pitch*, or the middle note of their primary register, which depends on the dimensions and physical constitution of the vocal ligaments. These varieties are, the *Bass*, the

* Physiology, lib. ix. p. 572.

Tenor, the *Contralto*, and the *Soprano*; the usual compass of each kind in the adult is represented in the annexed table.


Alto.
Soprano[*].
C D E F G A B C¹ D¹ E¹ F¹ G¹ A¹ B¹ C² D² E² F² G² A² B² C³ D³ E³ F³ G³ A³ B³ C⁴
Bass.
Tenor.

In addition to these characteristic and principal divisions of the voice, there are certain others called the *Baritone*, the *Mezzo-soprano*, and the *Soprano-sfogato*, which are subdivisions of the foregoing, and the place of either of which in the scale is indicated by its name. We see by this table what an extensive variety of harmonious sounds may be produced by the combinations of the different kinds of voice. In ordinary singers the range seldom exceeds two octaves, except in those endowed with a falsetto. There have been some celebrated singers, such as CATALANI, MALIBRAN, and others, whose compass has even exceeded three octaves, but such instances are rare. The voices in both male and female are nearly of the same pitch until the age of puberty, at which period the voice of males sinks an octave. This change of pitch is owing to a sudden enlargement of the larynx, whereof the antero-posterior diameter is augmented by from one-fourth to one-third, with a simultaneous lengthening of the vocal ligaments. During this process the voice is hoarse, and there is a temporary inability to regulate it. Eunuchs do not undergo this change. BENNATI is of opinion that the voice should not be exercised at this time of life, and in support of his views he cited the cases of DONZELLI and DONIZETTI, of whom the latter lost his voice by singing, whilst the former retained it by abstaining from singing at that period. There are, however, many examples of persons possessing fine voices, who never paid the least attention to this rule.

The oral, nasal, and pharyngeal cavities exercise an important influence on the quality of sounds after their production by the larynx. Further effects are ascribed by BENNATI to the arches of the palate, the uvula, and velum, all of which appear to contract with the acute, and relax with the grave tones, and are in constant motion during the modulation of the voice. The contraction of these parts during the production of acute sounds has also been observed by FABRICIUS AB AQUAPENDENTE, MEYER, GERDY, and DZONDI. BENNATI conceived, as has been already mentioned, that the falsetto notes, which he calls notes "sur laryngiennes," are produced exclusively in the superior part of the vocal tube, but it has been shown that this hypothesis is contrary to acoustic principles, and that the same motions of the palate are also equally observable during the production of acute tones of the ordinary register.

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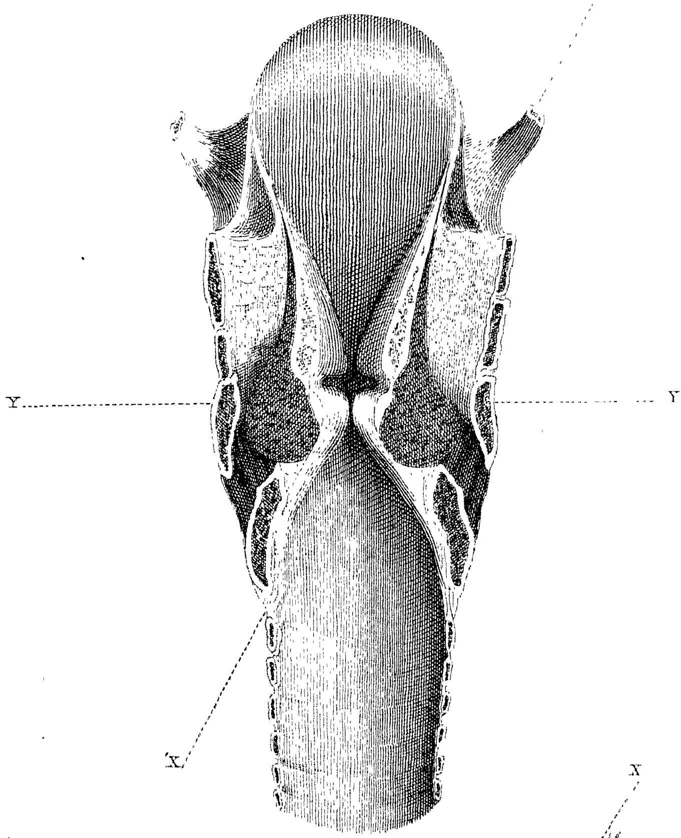
[*] The two first of these belong to the male sex, and the two last to the female. In this table C is the pitch of the 8-feet organ pipe, or the fundamental of the fourth string of the violoncello; the ciphers denote the octaves, that is, C^1, C^2, &c. are the first and second octave of C.

MÜLLER also states that the arches of the palate may be touched by the finger without altering the pitch, which could not be the case on the hypothesis of BENNATI. It is to be remarked that neither MÜLLER nor BENNATI mentions the opening of the crico-thyroid chink on sounding the first note in the falsetto register; neither do they mention the simultaneous falling of the larynx, and they deny the existence of a third register. According to the hypotheses of LEHFELDT and MÜLLER, any increased intensity of vocal sound ought to raise the pitch of the voice; but if this were the case, the performance of prolonged vocal sounds on the same note, but of variable intensity, would be rendered impossible without a simultaneous adjustment between the tension of the vocal ligaments and the current of air; whereas, by examining the state of the crico-thyroid chink during the utterance of such sounds, it is found that no such adjustment takes place. The exquisite quality of the sounds of the larynx, when modified by the oral and nasal cavities, renders the human voice far superior to any artificial musical instrument; since its tones glide through all the en-harmonic intervals between successive notes, an effect which no such instrument can perfectly imitate. DODART estimates the number of tones, which can be produced by the voice and appreciated by the ear in the compass of an octave, at three hundred: a striking proof of the complete control exercised by the laryngeal nerves over the vocal apparatus.

The action of the vocal organs in producing speech is a distinct branch of the physiology of voice which the author does not intend now to investigate. It is well known that the vowel sounds have been imitated by KRATZENSTEIN, DE KEMPELEN and WILLIS by means of mechanism, and that the principles on which they depend have been successfully analysed by the latter: but this is a subject which would require a very lengthened examination to render it the justice which its importance demands*.

Having now completed the investigation of the physiological character of the human organs of voice, and having for the sake of simplicity considered them in three distinct lights; namely, as membranous ligaments obeying the laws of musical strings, as a reeded instrument, and as a membranous pipe with a column of air vibrating within it, the results of the various experiments which have been noticed would certainly seem to warrant the conclusion that each of these views is correct; for it cannot be denied that these experiments clearly show the vocal apparatus to be influenced by the air expelled from the chest in precisely the same way as if it were a stretched cord, a reed, or a vibrating tube. Why then should we hesitate to adopt the obvious conclusion that the vocal organs do in fact combine the properties of these various instruments, and are themselves the perfect types of which these instruments are only imperfect imitations? The error of those who have preceded the author in this inquiry seems to consist in viewing the organs of voice, not as a com-

* The Abbé MICAL, FABER and Mr. WHEATSTONE have succeeded in producing articulate language by means of artificial mechanism; the Abbé, having so far completed the apparatus as to be capable of performing almost any sentence, appears to have destroyed his machinery owing to pecuniary disappointment.



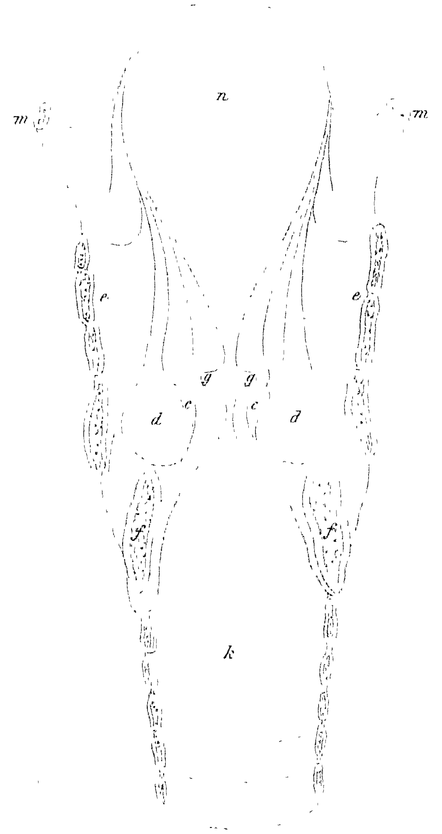


Fig. 2.

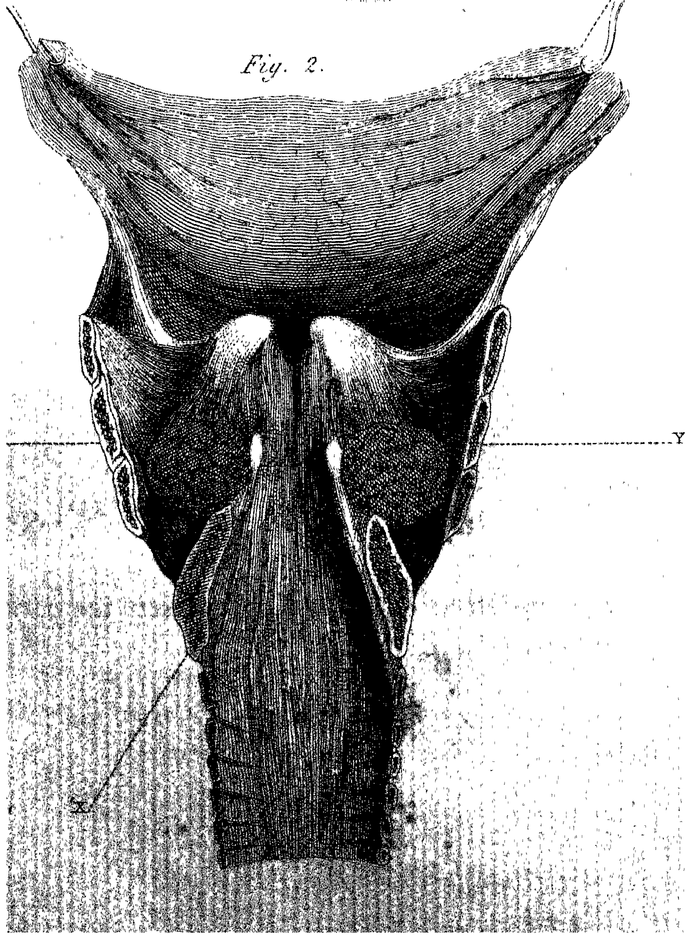
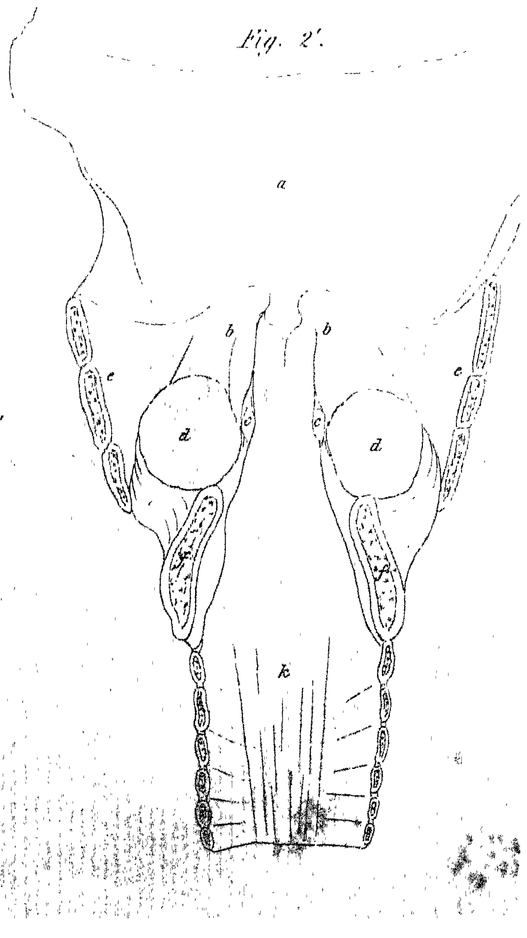


Fig. 2'.



plex, but as a simple apparatus; with some the favourite hypothesis has accordingly been that of musical strings, with others that of a reed, whilst experiments are equally in favour of both.

It cannot be expected that in this brief treatise, a subject, wherein, notwithstanding the attention hitherto bestowed on it for many years by men of the highest philosophical talent, so little comparatively has been effected, shall be at once exhausted, and all its difficulties removed; but the inductive method, the only satisfactory mode of reasoning on such subjects, has been most scrupulously pursued, and whatever explanations have been offered of the phenomena of the voice are at least founded on facts which are incontrovertibly established.

Description of the Plates.

PLATE XXX.

Figs. 1 and 2. The internal structure of the larynx brought into view, by making a transverse section through the central portion.

YY'. The plane of the vibrating position of the vocal ligaments.

XX. The plane of the respiratory position in which the vocal ligaments are found to lie in their most relaxed state.

Figs. 1' and 2' are outlines descriptive of figs. 1 and 2.

Fig. 1'. Anterior section of the larynx.

n. The epiglottis.
mm. Os hyoides.
ee. Internal surface of the thyroid cartilage.
ff. The cricoid cartilage.
dd. Thyro arytenoid muscles.
gg. The ventricles of Morgagni.
cc. Inferior vocal ligaments.
k. The trachea.

Fig. 2'. *a*. The pharynx.
b. The arytenoid cartilages. The letters *c*, *f*, *d*, *k*, &c. represent the parts corresponding to the same letters in fig. 1'.

PLATE XXXI.

The apparatus employed by Müller for making experiments on the human larynx.

Fig. 3. N. Shaft or column for the attachment of the larynx.

f. The forceps for compressing the larynx laterally.

u. The bellows.

v. The manometer connected with the tube *u* for estimating the tension of the air used in the experiments.

M. O. Columns for the attachment of the pulleys *x*′ and *y*′.

x. A line by means of which the vocal cords are extended in the direction of their length; it passes over the pulley *x*′.

y. A line passing over the pulley *y*′, by means of which the vocal cords may be relaxed and reduced to their minimum length, thus performing the office of the crico-thyroid muscle.

z. A line by means of which the vocal cords may be extended by drawing them downwards and forwards.

Fig. 4. Apparatus for the lateral compression of the vocal cords in the production of the chest tones.

a. A rod, to which the pincers *f* are attached, as *a*, fig. 3.

b. Cross beam, to which the pincers being attached may, by means of the part *c*, be moved backwards and forwards, in order to adjust them to the proper position for the length of the vocal cords, as *b*, fig. 3.

d. Screw for adjusting and securing the piece *c*.

e. Screw for adjusting the rod *a* to the height required for compressing the vocal cords.

f. The pincers.

Fig. 5. Compressor, with graduated scale for measuring the position of the legs *g*, *h*.

c, *d*. Screws for the approximation or separation of the legs *g*, *h*.

e. Projection by means of which the position of the leg *g* is indicated on the scale.

a b. The slab on which the compressor is fixed. It passes through the part *b*, represented in the apparatus, fig. 3, and may by these means be fixed in the required position.

Fig. 6. Compressor, with two moveable legs, for making experiments on the human larynx for the chest voice. The parts *c*, *d*, to which the legs *e*, *f* are attached by hinges, move in joints on the part *a b*, and may be fixed by screws. *g*, *h* are small cords, by means of which the legs may be made to approach by the application of weights.

Fig. 7. The glottis prepared for experiments. The arytenoid cartilages are firmly secured together behind the chink by means of a strong pin, and united by a ligature which serves to attach them securely to the column. The supe-

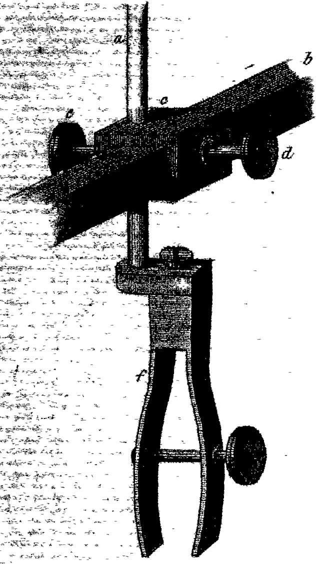


Fig. 7.

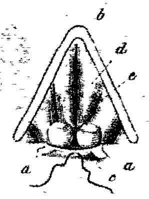


Fig. 3.

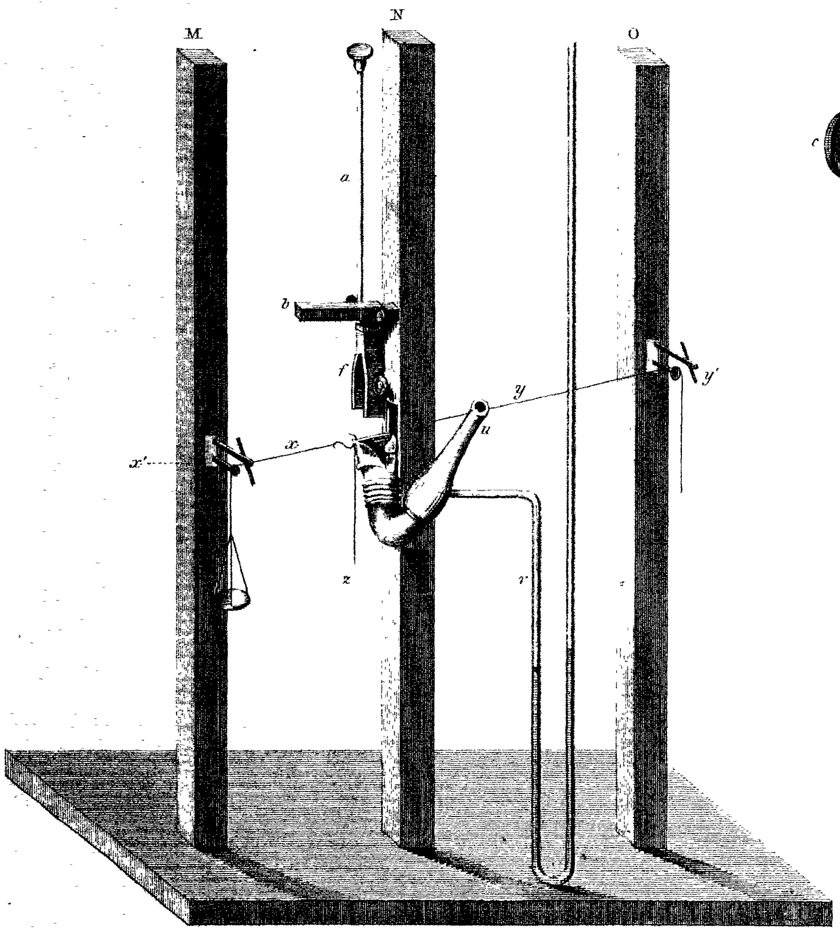


Fig. 5

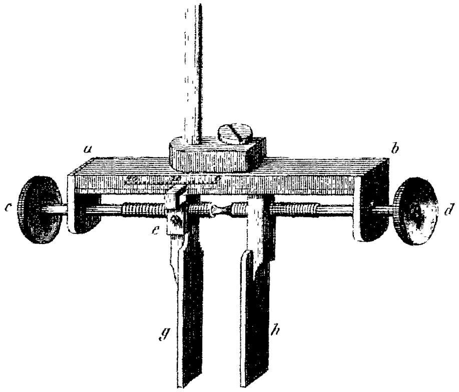


Fig 6.

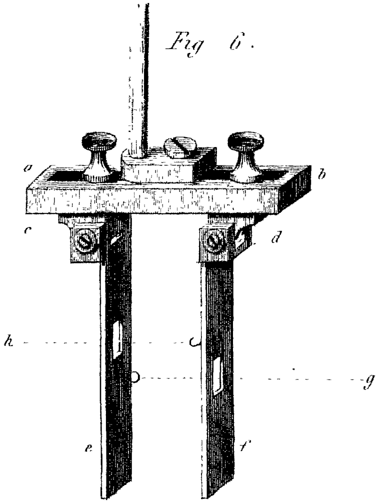
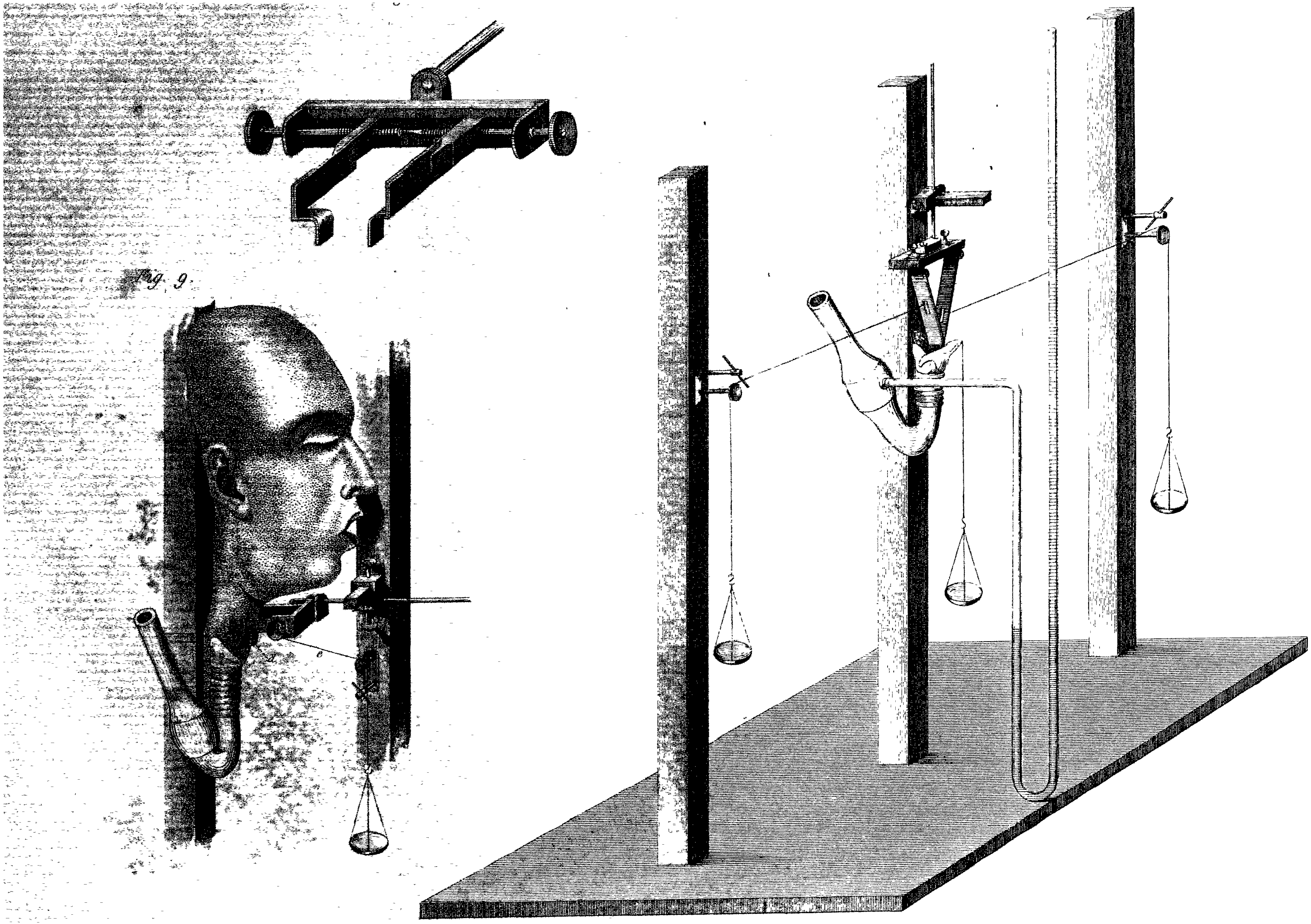


Fig. 9.



rior portion of the arytenoid cartilages and the thyroid, with all the parts above the inferior vocal cords, are removed, in order to leave the sides of the vocal cords free to admit the application of the compressor.

aa. The bases of the two arytenoid cartilages secured by a pin, and bound together.
b. Thyroid cartilage.
c. Cricoid.
d. Vocal cords.
e. Thyro-arytenoid muscles.

PLATE XXXII.

Fig. 8. Apparatus for experiments on the chest voice, under a graduated lateral compression of the vocal cords by means of the compressor.

Fig. 9. Represents the head and vocal organs prepared for experiments. The cervical vertebræ are removed, and the œsophagus opened behind the arytenoid cartilages, which are fixed together by a strong pin and ligature; the latter is brought through the opening, which is then firmly sewed together, and the lower opening of the œsophagus is also closed up. The larynx is laid bare, and the superior portion of the thyroid cartilage carefully removed so as not to injure the mucous membrane of the larynx. The parts thus prepared are firmly fixed against the column, to which the arytenoid cartilages are also attached by the cord which binds them together. The trachea is connected with a pipe and bellows for the supply of air.

a. The trachea.
b. The os hyoides.
c. The cricoid cartilage.
d. Portion of the thyroid cartilage remaining for the attachment of the cords *e*, by means of which the vocal cords may be extended.

Fig. 10. Compressor used in the apparatus, fig. 9, on a larger scale.

XXVIII. *On the Motion of Gases.*

By THOMAS GRAHAM, *Esq., F.R.S., Professor of Chemistry in University College, London; Hon. Fellow of the Royal Society of Edinburgh; Corresponding Member of the Royal Academies of Sciences of Berlin and Munich, of the National Institute of Washington, &c.*

Received June 18,—Read June 18, 1846.

THE spontaneous intermixture of different gases, and their passage under pressure through apertures in thin plates and by tubes, form a class of phenomena of which the laws have been only partially established by experiment. The separation of two gases by a porous screen, such as a plate of dry stucco, will prevent for a short time any sensible intermixture arising from slight inequalities of pressure, but such a barrier is readily overcome by the diffusive power of the gases, which is fully equal to their whole elastic force. Hence a cylindrical glass jar with a stucco top, filled with any gas and standing over water, affords the means of demonstrating the unequal diffusive velocities of air and the gas, by the final contraction or expansion of the gaseous contents of the jar, after the escape of the gas is completed. Compared with the volume of air which has entered, the volume of gas which has passed simultaneously outwards is found to be in the inverse proportion of the square root of the specific gravity of the gas. The diffusive velocities therefore of different gases are inversely as the square root of their densities; or the times of diffusion of equal volumes directly as the square root of the densities of the gases*.

Such is also the theoretical law of the passage of gases into a vacuum, according to the well-known theorem that the molecules of a gas rush into a vacuum with the velocity they would acquire by falling from the summit of an atmosphere of the gas of the same density throughout; while the height of such an atmosphere, composed of different gases, is inversely as their specific gravities. This is a particular case of the general law of the movement of fluids, well-established by observation for liquids, and extended by analogy to gases. The experiments which have already been made upon air and other gases, by M. P. S. GIRARD† and by Mr. FARADAY‡, are sufficient to show that the discharge of light is more rapid than that of heavy gases; and are interesting as first approximations, although incomplete and lending a very imperfect support to the theoretical law. Indeed some results obtained by these experimenters and others, appear wholly inconsistent with that law, such as Mr. Faraday's curious observations of the change of the relative rates of hydrogen and olefiant gases in passing through a capillary tube under different pressures; and my own observation, that carbonic acid gas is forced by pressure through a porous mass of stucco as quickly or more so than air is, although more than a half heavier; and that other gases pass in times which have no obvious relation to their diffusive velocities[*].

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* On the Law of the Diffusion of Gases; Transactions of the Royal Society of Edinburgh, vol. xii. p. 222; or Philosophical Magazine, 1834, vol. ii. pp. 175, 269, 351.

† Annales de Chimie, &c., 2de Sér., t. 16. p. 129.

‡ Quarterly Journal of Science, vol. iii. p. 354; and vol. vii. p. 106.

In studying this subject, I found that it was necessary to keep entirely apart the two cases of the passage of a gas through a small aperture in a thin plate and its passage through a tube of sensible length. The phenomena of the first class then became well-defined and simple, and quite agreeable to theory. Those of the second class also attained a high degree of regularity, where the tubes were of great length, or being short were of extremely small diameter. Capillary glass tubes, which varied in length from twenty feet to two inches, were found equally available and gave similar results, where a sufficient resistance was offered to the passage of the gas.

The rate of discharge of different gases from capillary tubes appears to be independent of the nature of the material of the tube, in so far as the rates were found to be similar for tubes of glass and copper, and even for a porous mass of stucco. But while the discharge by apertures in thin plates is found to be dependent in all gases upon a constant function of their specific gravity, the discharge of the same gases from tubes has no uniform relation to the density of the gases. Both hydrogen and carbonic acid, for instance, pass more quickly through a tube than oxygen, although the one is lighter and the other heavier than that gas. I shall assume then for the present, that in the passage of gases through tubes we have the interference of a new and peculiar property of gases; and on the ground of a radical difference in agency speak of the two classes of phenomena under different names. The passage of gases into a vacuum through an aperture in a thin plate I shall refer to as the *Effusion* of gases, and to their passage through a tube as the *Transpiration* of gases. The determination of the coefficients of effusion and transpiration of various gases will be the principal object of the following paper.

Part I.—EFFUSION OF GASES.

1. *Effusion into a Vacuum by a glass jet.*

The glass jet was formed from a short piece of a capillary thermometer tube, of which the bore was cylindrical, to which a conical termination was given by drawing it out when softened by heat and breaking the point. The aperture at the point of the jet was cylindrical, in a flat surface, and so small that it could only be seen distinctly by means of a magnifying-glass; its size, compared with other apertures, may be expressed by the statement that one cubic inch of air of the usual tension passed into a vacuum through this aperture in 2·18 seconds. By means of a perforated

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[*] Edinburgh Transactions, xii. 238.

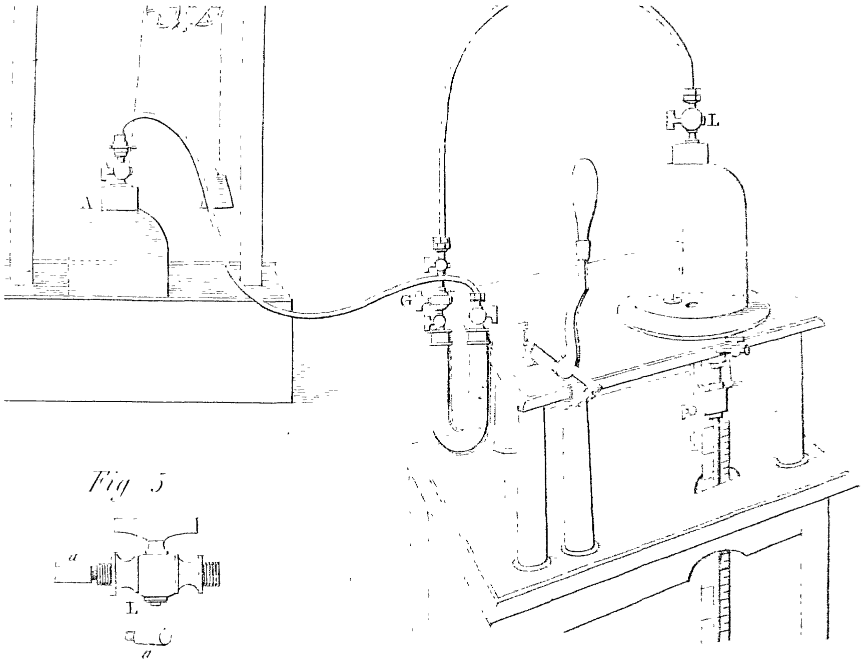


Fig 5

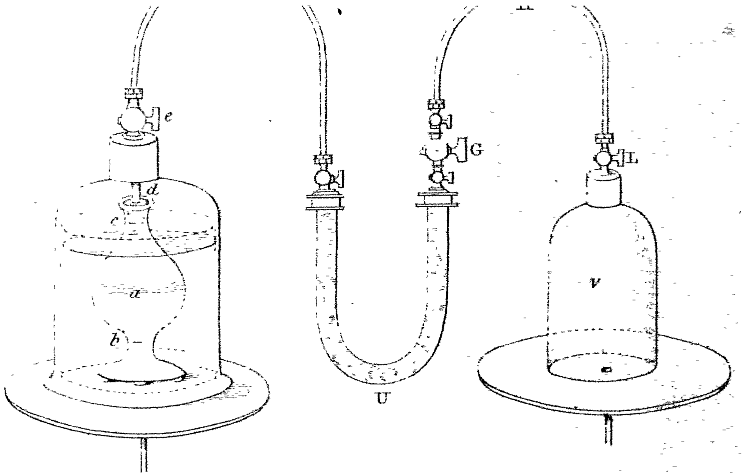


Fig 3.

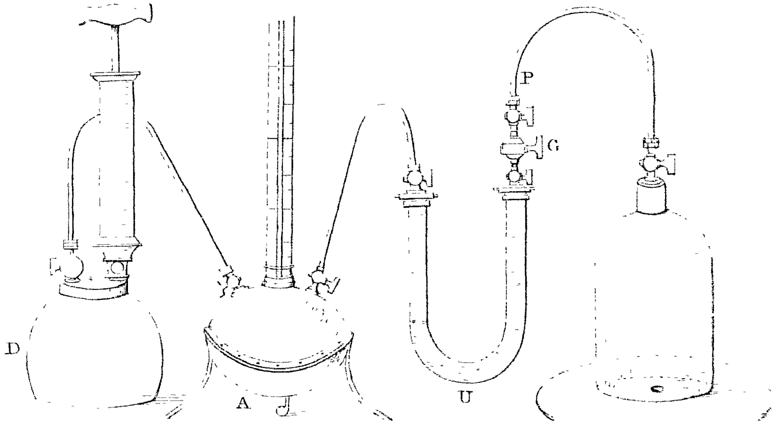
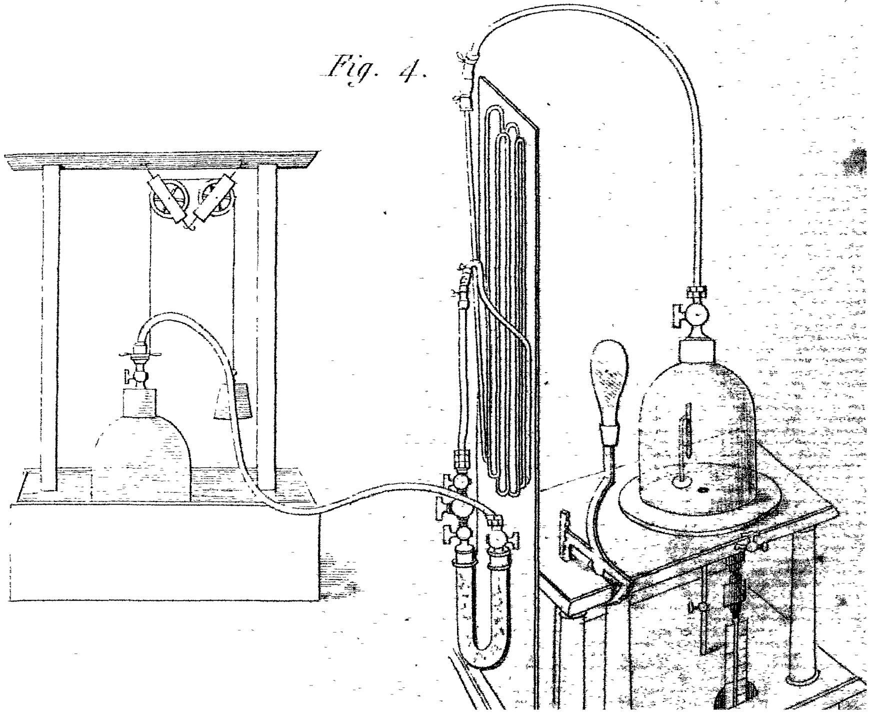


Fig. 4.



cork this glass jet was fixed within a block-tin tube, through which the gas was to be drawn; with the point of the tube directed towards the magazine of gas, so that the gas in passing towards the vacuum entered the conical point of the jet instead of issuing from it. This form of the aperture reduced the rubbing surface of glass to a thin ring, or made it equivalent to an aperture in a very thin plate; but the mode of placing the jet, or direction in which the current passed through the aperture, was found afterwards to be of little consequence.

The gas for an experiment was contained in a glass jar, of an elliptical form, balanced like a gasometer over water, and terminated at top and bottom with two short hollow cylindrical axes, of an inch in diameter; its capacity between two marks, one on each of the cylindrical ends, being 227 cubic inches. From this gasometer the gas was conveyed directly into a U-shaped drying tube, 18 inches in length and 0·8 inch in diameter, filled in some cases with fragments of chloride of calcium, in others with fragments of pumice-stone soaked in oil of vitriol; the pumice, when used, having been first washed with water, to deprive it of soluble chlorides. From the drying tube, the gas entered the tin tube occupied by the glass jet, one end of that tube being connected with the drying tube, and the other with an exhausted receiver on the plate of an air-pump. The apparatus described is exhibited in fig. 1 of Plate XXXIII., with the exception of the elliptical gasometer, the place of which is occupied there by the counterpoised jar A in the water-trough. The gas was thus forced through the minute aperture by the whole atmospheric pressure. In making an experiment with any other gas than atmospheric air, a considerable quantity of the gas was first blown through the drying tube, from the gasometer, to displace the air in the former; and to do this quickly an opening was made into the air-channel beyond the drying tube, at G, by which gas might be allowed to escape into the atmosphere without proceeding further or being drawn through the glass aperture into the vacuum. This side aperture was closed by a brass screw and leather washer. In making an experiment, the gasometer was filled with the gas to be effused, and then connected with the air-pump receiver, in which a constant degree of exhaustion was maintained by continued pumping. The interval of time was noted in seconds, which was required for the passage of a constant volume of gas, amounting to 227 cubic inches, namely, that contained between the two marks in the elliptical gasometer. Or, the volume of gas effused was more strictly 227 cubic inches, minus the volume of aqueous vapour which saturates air at the temperature of the experiment; the vapour being withdrawn from the gas, after it left the elliptical measure and before it reached the effusion aperture. It is scarcely necessary to add that great care is necessary during these and all other experiments on gases, to maintain a uniform temperature. The use of a fire or stove in the room in which the experiments were conducted was therefore avoided, and such arrangements made that the temperature was kept for five or six hours within a range of a single degree of FAHRENHEIT's scale.

Hydrogen.—In the experiments first made with air and hydrogen the temperature was 59° Fahr., and the height of the barometer 30·14 inches; a uniform exhaustion was maintained in the air-pump receiver of 29·3 inches, as observed by the gauge barometer attached.

The constant volume of dry air passed into the vacuum, or was effused, in three experiments, in 494, 495, and again in 495 seconds.

The constant volume of dry hydrogen was effused, in two experiments, in 137 and again in 137 seconds. Calculating from 495 seconds as the time for air, we have—

Time of effusion of air	1·
Time of effusion of hydrogen	0·277

Or, the result may be otherwise expressed, taking the reciprocals of the last numbers:

Velocity of effusion of air	1
Velocity of effusion of hydrogen	3·613

The specific gravity of hydrogen gas, according to the most recent and exact determination, that of Regnault, is 0·06926, referred to air as unity; of which the square root is 0·2632, and the reciprocal of the square root 3·7994; to which the numbers for the time and velocity of hydrogen above certainly approximate.

Oxygen and Nitrogen.—Temperature 60°; exhaustion maintained at 29·3 inches. The constant volume of air was effused in 494 seconds, of oxygen in 520 seconds, and of nitrogen in 486 seconds, in one experiment made upon each gas. Hence the following results:

	Time of effusion.	Square root of density.	Velocity of effusion.	Reciprocal of square root of density.
Air	1	1	1	1
Oxygen	1·053	1·0515	0·9500	0·9510
Nitrogen.........................	0·984	0·9856	1·0164	1·0146

The densities made use of are those of M. Regnault, namely, 1·10563 for oxygen, and 0·97137 for nitrogen. It will be observed, that the times of effusion of these two gases correspond as closely with the square roots of their densities as the mode of observation will admit of; the times observed being within one second of the theoretical times.

Carbonic Oxide.—This gas was prepared by the action of oil of vitriol upon pure crystallized oxalic acid, and subsequent washing with alkali. The temperature during the effusive experiment was 60°·3; the usual exhaustion was maintained. The time of effusion of air was 494 seconds; of the same volume of carbonic oxide 488 seconds:

	Time of effusion, air =1.	Square root of density.	Velocity of effusion.	Reciprocal of square root.
Carbonic oxide	0·987	0·9838	1·0123	1·0165

The effusion-rate of this gas approaches therefore very closely to the theoretical number. In the calculations the density of carbonic oxide is taken at 0·96779, as found by WREDE.

Carburetted Hydrogen., CH_2.—This was the gas of the acetates, prepared by heating a mixture of acetate of soda with dry hydrate of potash and lime.

The temperature of the gases effused being 59°·5, and the exhaustion 29·3 inches; the constant volume of air passed through the aperture in 493 seconds, of carburetted hydrogen in 373 seconds:

	Time, air =1.	Theoretical time.	Velocity.	Theoretical velocity.
Carburetted hydrogen	0·756	0·7449	1·322	1·3424

The density of carburetted hydrogen is taken at 0·5549 in the calculations.

Carbonic Acid and Nitrous Oxide.—In the first experiment with carbonic acid, the gasometer with the gas was floated as usual over water; thermometer 58°·5. The effusion of air took place in 495 seconds, of carbonic acid in 595 seconds. To diminish the loss of the latter gas occasioned by its solubility in water, a second experiment was made over brine: the time required by the carbonic acid was now 603 seconds. The velocity of effusion of carbonic acid is by the first experiment 0·832; by the second it approaches more nearly the theoretical number, calculated from 1·52901 (REGNAULT) as the density of this gas, as appears below:

	Time, air =1.	Theoretical time.	Velocity.	Theoretical velocity.
Carbonic acid.................	1·218	1·2365	0·821	0·8087

The observation on nitrous oxide was made on a different occasion, with a temperature of 62°·5. The time of effusion of air was then 488 seconds; of nitrous oxide 585 seconds, the gas being collected over water:

	Time, air =1.	Theoretical time.	Velocity.	Theoretical velocity.
Nitrous oxide.................	1·199	1·2365	0·834	0·8087

The specific gravity of nitrous oxide is assumed in the calculations to be the same as that of carbonic acid. The time of effusion of both of these gases is shortened by the loss of a portion of the gas, by solution in the water of the pneumatic trough during the period of the experiment, and falls below the theoretical number. In carbonic acid over brine, where the injury is least from this cause, the observed velocity is, however, still within one-seventieth part of that calculated from the specific gravity of the gas.

Olefiant Gas.—When this gas is prepared by heating sulphuric acid, of specific gravity 1·6, with strong alcohol at the temperature of 320°, in the proportion of six parts of the former to one of the latter, it appears to come off at first very pure, as it is entirely absorbed by the perchloride of antimony, and contains therefore no carbonic oxide. But it is really contaminated, I find, by a portion of another heavier gas or vapour (not ether vapour), which cannot be entirely removed from it by washing with alkaline water, oil of vitriol, or strong alcohol, and which may raise the density of the gas above that of air. As the evolution of gas proceeds, the proportion of the heavy compound diminishes, and it finally disappears, and the gas attains its theoretical density; but it is then again contaminated with more or less carbonic oxide. The latter gas, however, being of sensibly the same density as olefiant gas, is not likely to exert any influence upon its effusion rate. But before these facts were ascertained this jet became unserviceable from an accident, and the experiments made with it were all made upon the dense olefiant gas, and gave an effusion time which slightly exceeded that of air.

2. *Effusion into a Vacuum by a perforated brass plate* A.

A minute circular aperture was made by means of a fine drill in a thin plate of sheet brass $\frac{1}{228}$th of an inch thick, and the opening still further diminished by blows from a small hammer, of which the surface was rounded. A small disc of the brass plate was then punched out, having the aperture in the centre, which was soldered upon the end of a short piece of brass tube, of quill size, so as to close the end of the cylinder. This brass tube was then fixed, by means of a perforated cork, within the tin tube, used as formerly, for conveying the gas from the gasometer jar to the air-pump receiver; so that the gas should necessarily flow through the small aperture in its passage, as before through the glass jet. The aperture was of an irregular triangular form, in consequence of the hammering of the plate. One cubic inch of air of usual tension passed into a vacuum through this aperture in 12·56 seconds. The volume of gas effused in an experiment was the same as before, and the other arrangements similar, but the aperture in the brass plate being smaller than that of the glass jet, the effusion was considerably slower.

The constant volume of 227 cubic inches of the following gases passed into a vacuum of 29·3 inches by the attached mercurial gauge, at the temperature of 63°·3, in the following times:—

(1.) Air in 47′ 32″, or 2852 seconds.
(2.) Nitrogen in 46′ 47″, or 2807 seconds.
(3.) Oxygen in 50′ 1″, or 3001 seconds.
(4.) Hydrogen in 13′ 8″, or 788 seconds.
(5.) Carbonic acid (over brine) in 56′ 54″, or 3414 seconds.

These results, referred to air as unity, are as follows:—

	Time of effusion.	Theoretical time.	Velocity of effusion.	Theoretical velocity.
Air	1	1	1	1
Nitrogen	0·9842	0·9856	1·0160	1·0146
Oxygen	1·0502	1·0515	0·9503	0·9510
Hydrogen	0·2763	0·2632	3·607	3·7994
Carbonic acid	1·1971	1·2365	0·8354	0·8087

The experimental results of the velocity of effusion of nitrogen and oxygen accord very closely with theory, the velocity of the first being only 0·0014 in excess, and the second 0·0007 in deficiency. Indeed the differences fall within the unavoidable errors of observation in determining the specific gravity of these gases, unless conducted with the greatest precautions. Of hydrogen, the velocity of effusion observed is 3·607 times instead of 3·80 times greater than air. It thus suffers a small but sensible reduction of its velocity, which can be referred, as will afterwards appear, to the thickness of the plate and the aperture being in consequence sensibly tubular. A portion of the carbonic acid gas must have been absorbed by the brine during the long continuance of the experiment, nearly an hour; to which the quickness of the rate of that gas may be referred; the velocity of its passage being thus apparently increased from 0·81 to 0·835.

The experiment was varied by observing the time in which gas entered a vacuous receiver upon the plate of the air-pump, in quantity sufficient to depress the gauge barometer from 28 to 23 inches. An exhaustion was always made at first of upwards of 29 inches, and the instant noted at which the mercury passed the 28th and 23rd inches of the scale. The times of effusion were as follows, the temperature being 66°.

	Experiments.				Velocity of effusion.	
	1.	2.	3.	Mean.	Observed.	Calculated.
Air	474	474	....	474	1	1
Oxygen	501	502	499	500·7	0·9467	0·9510
Nitrogen	468	469	....	468·5	1·0117	1·0146
Olefiant gas	467	469	....	468	1·0128	1·0147
Carburetted hydrogen	357	....	....	337	1·3278	1·3369
Carbonic acid	573	573	....	573	0·8272	0·8087

The same close correspondence is manifest here between the observed and calculated velocities.

The whole results leave no doubt of the truth of the general law, that *different gases pass through minute apertures into a vacuum in times which are as the square roots of their respective specific gravities; or with velocities which are inversely as the square roots of their specific gravities;* that is, according to the same law as gases diffuse into each other.

It appears that the proper effect of effusion can only be brought out in a perfect manner when the gas passes through an aperture in a plate of no sensible thickness, for when the opening becomes a tube, however short, the effluent gas meets a new resistance which varies in the different gases according to an entirely different law from their rates of effusion, namely, the resistance of transpiration. The deviation is most considerable in hydrogen, which rapidly loses velocity if carried through a tubular opening, when compared with air. This was illustrated by experiments made upon the glass jet of the former observations; which was operated upon in four different conditions as to length. The point had been drawn out rather long at first, so that it admitted of portions of 0·2 inch, 0·1 inch, and 0·07 inch, being broken off successively before it was reduced to the form of a blunt cone, which it had when used in the experiments already detailed. Air and hydrogen were effused from this jet into the exhausted receiver till the mercurial gauge fell from 28 to 4 inches, with the jet in the different states described.

When the glass jet was of greatest length, the time of air was 335 and 337 seconds in two experiments, and of hydrogen 120 seconds in two experiments; which give 2·800 as the velocity of effusion of hydrogen.

After the first portion was broken from the point, by which of course the aperture was enlarged, the time of air was 175 seconds in two experiments, of hydrogen 55 and 56 seconds; giving 3·153 for the effusive velocity of hydrogen.

After the second abridgement in its length, the time of passage of air by the jet was 110 seconds in two experiments, of hydrogen 33, 32 and 33 seconds in three experiments; giving 3·33 for the velocity of hydrogen.

When still further reduced in length, a larger jar being used as the vacuous receiver, the time of air was in two experiments 408 and 410 seconds; of hydrogen in three experiments, 122, 120 and 122 seconds, giving 3·38 for the velocity of hydrogen. Thus, as the jet was progressively shortened, the relative velocity of the passage of hydrogen continually rose, passing through the numbers 2·8, 3·153, 3·33 and 3·38. By reversing the direction of the stream of gas through the aperture in its last condition, the effect of friction was still further diminished, and the velocity of hydrogen raised to 3·61, as in the experiments previously recorded, which were made with this jet in an inverted position. It may be fairly presumed, therefore, that if the length of the tube or thickness of the plate containing the aperture was still further diminished, the effusive velocity of hydrogen, compared with air, would be increased, and approximate more nearly to 3·80, the theoretical number.

The tubularity of the opening quickens, on the contrary, the passage of carbonic acid and nitrous oxide in reference to air; for these gases are more transpirable than air, although less effusive: hence their observed time of effusion is always sensibly less than their calculated time.

3. *Effusion of Nitrogen and Oxygen, and of mixtures of these Gases under different pressures, by a second perforated brass plate* B.

This brass plate was of the same thickness as the last ($\frac{1}{228}$th of an inch); the aperture was circular and also $\frac{1}{228}$th of an inch in diameter, as measured by a micrometer; and the velocity with which air of the usual tension passed into a vacuum by the aperture, one cubic inch in 6·08 seconds. The rate of passage was therefore rather more than twice as quick as by the first perforated plate A.

A two-pint jar was used as the air-pump receiver, or aspirator-jar, as it may be called; and the capacity of the vacuous space into which the gas effuses, including the tubes and channels of the air-pump as well as the jar, was found to be 72·54 cub. in. An exhaustion was always first made of about 29 inches by the gauge barometer of the pump, and then the gas allowed to enter from a counterpoised bell-jar over water (fig. 1, Plate XXXIII.). The instant was noted at which the mercury fell to 28 inches, when the observation began, and again at 20 and 12 inches, or after two intervals of 8 inches each; and again at 4 and 2 inches by the gauge barometer. The experiments were made successively on the same day in the order given, with the barometer at 29·34 inches and thermometer at 49°. A small thermometer placed within the aspirator-jar was observed to rise 1° FAHR. very uniformly during the continuance of an experiment. The effusion of air is repeated at the close of the experiments to determine whether or not any change of rate had occurred during their continuance.

TABLE I.—Effusion.

Gauge barometer in inches.	Air.		Nitrogen.		Oxygen.		Mixture of 50 nitrogen + 50 oxygen.	
	I.	II.	I.	II.	I.	II.	I.	II.
	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0
20	120	120	119	119	126	126	122	122
12	123	122	120	120	128	130	125	125
8	68	68	67	67	72	72	70	69
4	84	84	83	83	89	88	85	86
2	57	57	55	54	59	59	57	57
	452	451	444	444	474	475	459	459

TABLE II.—Effusion.

Gauge barometer in inches.	25 nitrogen + 75 oxygen.		75 nitrogen + 25 oxygen.		Air.
	I.	II.	I.	II.	
	″	″	″	″	″
28	0	0	0	0	0
20	122	122	122	121	120
12	125	125	122	122	123
8	70	69	68	68	68
4	85	86	85	85	83
2	57	57	56	56	57
	459	459	453	453	451

The near approach to equality in the times from 28 to 20, and from 20 to 12 inches throughout the whole of these experiments, is very remarkable. Under an average pressure of 24 inches in the former portion of the scale and of 16 in the latter, the gases effuse with nearly equal velocities; which confirms the observation of MM. De Saint-Venant and Wantzel, on the passage of air through a minute aperture, namely, that above two-fifths of an atmosphere, the further increase of the pressure is attended with a very slight increase in the velocity of passage*. In the experiments above with an increase of pressure from 16 to 24, or of one-half, the increase in velocity is not in general more than one-sixtieth part.

In the table which follows the average times are given, which the gauge barometer required to fall from 28 to 12 inches, and from 12 to 4 inches, taken from the preceding table, for air, nitrogen and oxygen, and also the ratio between the times of these gases, that of air being taken as unity, with their relative velocities, also referred to the velocity of air.

Gauge barometer.	Time in seconds.			Time of air = 1.		Velocity of air = 1.	
	Air.	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.
From 28 to 12 inches.	242·5	239	255·0	0·9855	1·0515	1·0146	0·9510
From 12 to 4 inches.	152·0	150	160·5	0·9868	1·0558	1·0133	0·9470

These results do not indicate any material difference between the ratios of effusion of these gases at different pressures. At the low as well as the high pressure, the velocities are in close accordance with the law of effusion; indeed they correspond as closely as the shortness of the time of observation justifies any inference; the small deviations observable being quite within the amount of errors of observation.

The results for the mixtures of oxygen and nitrogen are as follows, for similar divisions of the scale:—

Gauge barometer.	Time in seconds.			Time, air = 1.		
	I. 50 N + 50 O.	II. 25 N + 75 O.	III. 75 N + 25 O.	I. Mixture.	II. Mixture.	III. Mixture.
From 28 to 12 inches.	247	252	243·5	1·0185	1·0391	1·0041
From 12 to 4 inches.	155	157	153	1·0197	1·0329	1·0066

In these instances, as well as in the unmixed gases, the results do not justify the inference of any difference in the ratios of effusion at low from the ratios which hold at high pressures.

It appears, on comparing the times observed of the mixtures with the times calculated from the unmixed gases, that they sensibly agree. Thus the mean rate or time of 50 nitrogen + 50 oxygen, or square root of the specific gravity of that mixture, is 1·0191, the observed rate 1·0185; of 25 nitrogen + 75 oxygen, the mean rate is 1·0354, the observed rate 1·0391; of 75 nitrogen + 25 oxygen, the mean rate is 1·0025, the observed time 1·0041, in the range between 28 and 12 inches of the gauge barometer. Lastly, the particular mixture forming atmospheric air has already been seen to have the rate corresponding with its specific gravity or its composition. It may hence be inferred that any mixture of oxygen and nitrogen will possess the average rate of effusion of its constituent gases.

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* Journal de l'Ecole Royale Polytechnique, tome xvi. 27^{me} Cahier, 1839, p. 85. This memoir contains a valuable mathematical discussion of the velocities with which air flows into a receiver at different degrees of exhaustion.

4. *Effusion of Air, Carbonic Oxide, Oxygen, and of a mixture of Carbonic Oxide and Oxygen at different pressures, by **Plate** B.*

The carbonic oxide was prepared according to Mr. Fownes's process, by heating oil of vitriol upon ferrocyanide of potassium: the gas was collected, as a measure of precaution, over alkali.

The arrangements were similar to the last; barometer at 29·29 inches, thermometer 52°.

Table III.—Effusion.

Gauge barometer in inches.	Air.		Carbonic oxide.		Oxygen.		Mixture of 50 carbonic oxide + 50 oxygen.	
	I.	II.	I.	II.	I.	II.	I.	II.
	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0
20	118	119	116	117	125	126	121	121
12	120	120	118	117	126	126	123	122
8	67	66	66	66	71	71	68	68
4	81	82	80	81	86	86	83	83
2	56	56	55	55	60	60	58	58
	442	443	435	436	468	469	453	452

The passage of the gases is somewhat quicker throughout than in the preceding experiments with the same plate, but the ratio between their velocities remains constant.

Comparing again the same portions of the scale, we have—

Gauge barometer.	Time in seconds.				Time, air = 1.		
	Air.	Carbonic oxide.	Oxygen.	Mixture.	Carbonic oxide.	Oxygen.	Mixture.
From 28 to 12 inches	238·5	234	251·5	243	0·9811	1·0545	1·0188
From 12 to 4 inches	148	146·5	157	151	0·9898	1·0608	1·0202

Taking 0·96779 as the specific gravity of carbonic oxide, the square root is 0·9838, which corresponds closely with the observed time above, being intermediate between the times for the two different portions of the scale.

The time of effusion also of the mixture of carbonic oxide and oxygen in equal volumes is obviously the square root of the density of the mixture of the two gases:

Observed time of mixture	1·0188
Calculated time of gases	1·0182

The observed time of effusion of the mixture being within one thousandth part of the calculated time.

5. *Effusion of Carbonic Acid, Air, and of mixtures of Carbonic Acid and Air, at different pressures, by Plate* B.

The arrangements continued the same as in last experiments; barometer 29·58 in.; thermometer 49°.

TABLE IV.—Effusion.

Gauge barom. in inches.	Air.		Carbonic acid.		First mixture, $75CO_2+25$ air.		Second mixture, $50CO_2+50$ air.		Third mixture, $25CO_2+75$ air.	
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
	″	″	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0	0	0
20	121	121	145	146	141	140	135	134	128	128
12	123	123	150	149	143	143	137	137	131	131
8	69	70	83	84	81	80	76	77	74	73
4	85	84	103	103	98	99	95	94	90	90
2	58	59	71	70	68	67	64	64	61	61
	456	457	552	552	531	529	507	506	484	483

Comparing again the times in the two divisions of the scale adopted in the preceding tables:

Time in Seconds.

Gauge barometer.	Air.	Carbonic acid.	Mixture I.	Mixture II.	Mixture III.
From 28 to 12 inches.	244	295	283·5	271·5	259
From 12 to 4 inches.	154	187	179	171	163·5

Time of Effusion, time of Air = 1.

Gauge barometer.	Carbonic acid.		Mixture I.		Mixture II.		Mixture III.	
	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.
From 28 to 12 inches.	1·2090	1·2365	1·1618	1·1818	1·1127	1·1245	1·0618	1·0647
From 12 to 4 inches.	1·2143	1·2365						

The calculated number for carbonic acid (1·2365) is the theoretical time, or square root of the density of the gas; the calculated times for the mixtures are also the square roots of the respective gravities of those mixtures.

The times of effusion of carbonic acid compared with air do not therefore differ more than the numbers 1·209 and 1·214, in the two divisions of the scale; or 1 part in 242, a deviation which may be considered as within the errors of observation.

The mixtures of carbonic acid and air have also the mean times of the pure gases.

6. *Effusion of mixtures containing Hydrogen.*

[*] [I was induced to examine the effusion of mixtures of hydrogen and other gases very minutely, in order to elucidate if possible certain singular peculiarities which were observed in the transpiration of these mixtures by tubes. A new plate E was employed, composed of thin platinum foil $\frac{1}{765}$th of an inch in thickness, with a circular aperture $\frac{1}{260}$th of an inch in diameter, as measured by Mr. Powell by means of a micrometer. It was desirable to simplify the experiment at the same time by operating upon a constant volume of gas, measured before effusion, and drawn into an aspirator-jar which was maintained vacuous, or as nearly so as possible, by uninterrupted exhaustion. The gas was measured in a globular jar, to which more particular reference will be made hereafter. It contained 65 cubic inches between two marks, one upon each of its tubular axes, and was supported vertically over the water of a pneumatic trough.

The little brass tube upon which the perforated plate is fixed (*a.* in fig. 5, Plate XXXIII.) was now made to screw upon the end of one of the stop-cocks, namely, L (fig. 1.), which is immediately attached to the aspirator-jar, and projected upwards within the block tin tube H. The perforated plate was fixed to the end of its brass tube by means of soft solder.

The results thus obtained I consider superior in value to those already detailed, from the longer periods of observation, the time for air generally amounting to 800 or 900 seconds; from the new plate being thinner and its aperture of a regular circular form; and from the greater simplicity of the conditions of the experiment, namely, the passage of the gases into a sustained vacuum under the whole atmospheric pressure.

The series of experiments is divided into five sections, each containing the experiments of one day, to which the height of the barometer and the temperature are added. Two observations were made of the time of effusion in seconds for each gas, which are given under the columns of experiments I. and II., and the mean of the two experiments is added in a third column. This mean is expressed in the column which follows, with reference to the time of oxygen as 1. The additional column headed "calculated times of mixtures, oxygen = 1," contains times of the mixtures, calculated from their specific gravities, being the square roots of the densities of the respective mixtures. The observed times of the hydrogen mixtures will be seen to correspond very closely with these calculated numbers, the maximum divergences not exceeding that of pure hydrogen itself.

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[*] The passages and tables in this paper, which are inclosed in brackets, as the following to p. 587, have been added during the progress of the paper through the press, and the date of the addition is in each case noted at the end of the last paragraph.—S. H. C.

Table V.—Effusion into a sustained vacuum by platinum plate E.

	I.	II.	Mean.	Oxygen = 1.	Cal. time, Oxygen = 1.	Barometer.	Temp. Fahr.
Section I.							
Oxygen	909	909	909	1·0000	....	30·396	68°
Air	866	865	865·5	0·9521			
Hydrogen	242	242	242	0·2662			
Carburetted hydrogen ...	624	622	623	0·6853			
Carbonic oxide	849	850	849·5	0·9345			
Nitrogen	850	851	850·5	0·9356			
Air	864						
Carbonic acid	1053	1051	1052	1·1573			
Section II.							
Oxygen	912	912	912	1·0000	....	30·288	66
Air	868	867	867·5	0·9512			
Hydrogen	240	240	240	0·2631			
25H+75 Air	756	756	756	0·8289	0·8328		
50H+50 Air	633	633	633	0·6940	0·6951		
75H+25 Air	483	483	483	0·5296	0·5224		
80H+20 Air	444	444	444	0·4868	0·4805		
90H+10 Air	358	358	358	0·3925	0·3830		
95H+ 5 Air	309	309	309	0·3388	0·3296		
Air	864						
Section III.							
Oxygen	912	910	911	1·0000	....	30·219	66
Air	867	865	866	0·9506			
Hydrogen	239	241	240	0·2634			
12·5H+87·5O	853	855	854	0·9374	0·9396		
25 H+75 O	796	796	796	0·8737	0·8750		
37·5H+62·5O	733	733	733	0·8046	0·7990		
50 H+50 O	661	661	661	0·7255	0·7289		
62·5H+37·5O	586	586	585·5	0·6427	0·6435		
75 H+25 O	501	501	501	0·5499	0·5449		
80 H+20 O	460	461	460·5	0·5055	0·5000		
90 H+10 O	368	368	368	0·4039	0·3954		
95 H+ 5 O	312	312	312	0·3424	0·3309		
Air	860						
Section IV.							
Oxygen	914	913	913·5	1·0000	....	29·673	64
Air	870	869	869·5	0·9518			
Carbonic oxide	854	853	853·5	0·9343			
Hydrogen	238	239	238·5	0·2610			
25H+75CO	749	748	748·5	0·8193	0·8199		
50H+50CO	626	626	626	0·6852	0·6848		
75H+25CO	478	478	478	0·5231	0·5155		
80H+20CO	445	445	445	0·4871	0·4745		
90H+10CO	360	360	360	0·3940	0·3793		
95H+ 5CO	314	314	314	0·3437	0·3213		
Air	870						
Section V.							
Oxygen	915	914	914·5	1·0000	....	29·500	63
Air	870	869	869·5	0·9508			
Nitrogen	855	854	854·5	0·9344			
Hydrogen	241	241	241	0·2635			
25H+75N	753	753	753	0·8234	0·8213		
50H+50N	631	631	631	0·6899	0·6859		
75H+25N	480	478	479	0·5238	0·5163		
80H+20N	442	442	442	0·4833	0·4752		
90H+10N	359	359	359	0·3925	0·3797		
95H+ 5N	309	310	309·5	0·3379	0·3215		
Hydrogen	241						
Air	869						

The principal results of the preceding table, and also the results of two series of experiments or mixtures of hydrogen with carburetted hydrogen (C H_2) and with carbonic acid, are exhibited by means of the curves projected in Plate XXXIV, for the purpose of comparing with them the results of the transpiration of the same mixtures exhibited in Plate XXXV, which I have not yet succeeded in reconciling with any physical law. Feb. 1846.]

The numbers at the top and bottom of the Plate, which apply to the vertical lines, express the times of effusion, the time of oxygen being taken as 100; while the numbers to the right of the table, and which apply to the horizontal lines, express the volumes of hydrogen in 100 volumes of the mixture. Thus the curves all terminate above in a common point, 26·3, the time of 100 hydrogen; and each terminates below with the proper time of the particular gas which is mixed with hydrogen, the proportion of hydrogen being then 0, and that of the other gas 100; that is, the curve of the carburetted hydrogen mixtures at 72·32; the curve of the nitrogen mixtures at 93·5; that of the air mixtures at 95·1; that of the oxygen mixtures at 100, and that of the carbonic acid mixtures at 116.

7. *Effusion of Air of different Elasticities or Densities, by brass plate* B.

In all the experiments hitherto described, the air or gas effused was under the atmospheric pressure, which varied only within narrow limits. It was desirable to know whether the time remained constant for the passage into a vacuum of equal volumes of air of all densities, which the theory of the passage of fluids into a vacuum requires.

The air was drawn into the receiver of an air-pump (fig. 2. Plate XXXIII.), maintained vacuous by continued pumping, from the globular gas receiver *a*, placed in a deep glass basin half-filled with water and used as a pneumatic trough; this basin and the globular vessel being placed on the plate of a second air-pump under a large bell-jar in which a partial exhaustion could be maintained during the continuance of the experiment. The vessel *a* had tubular openings at top and bottom; its capacity between the marks *b* and *c* in these necks was 65 cubic inches; the lower tube was expanded under the mark *b* into an open funnel; the upper tube was cylindrical with a flange or lip, and had a sound cork fitted into it. A short brass tube *d*, of quill size, soldered to the end of the stopcock *e*, descended into the bell-jar and passed through the cork of *a*, which was perforated. The vessel *a* having thus an air-tight communication with the exhausted receiver *v* of the first air-pump, by the tube F, the drying tube U and the tube H; a measured quantity of air (65 cubic inches) could be drawn from it by observing the time which the water of the trough took to rise from the mark *b* to *c*. The perforated brass plate, through which the gas had to pass, was attached to the stopcock L, as before, and was therefore within the tube H. It is represented of one-fourth of its linear dimensions in fig. 5, Plate XXXIII.

When the large bell-jar over *a* was not exhausted, the gas in the latter was of the atmospheric tension. With the barometer at 29·28 inches, and thermometer at 54°, the air was withdrawn from the globe *a*, in 388 seconds in one experiment, and in 389 seconds in another.

The pressure upon the air in *a* was then reduced to three-fourths of an atmosphere, by exhausting so that the gauge barometer stood at 7·32 inches from the bottom of the scale, which is one-fourth of the whole pressure of 29·28 inches. The globe *a* was thus occupied by air of the tension of three-fourths of an atmosphere, or 21·96 inches. It was in this state connected with the vacuous receiver *v* of the air-pump, and the time required for the effusion of the constant volume of 65 cubic inches of air, measured in its rarefied state, between the marks *b* and *c*, observed. The effusion of this volume of air of three-fourths density was effected in two experiments in 389 and 392 seconds.

Again, the air in *a* being made of 14·64 inches tension, or half an atmosphere, the constant volume was effused into a vacuum in 411 and 408 seconds.

Lastly, with the air in *a* of 7·32 inches tension, or one-fourth of an atmosphere, the time of effusion was 438 and 439 seconds. The results therefore of the effusion of a constant volume are as follows:—

	Time of effusion.	
Air of 1 atmosphere	388·5 seconds . . .	1.
Air of 0·75 atmosphere	390·5 seconds . . .	1·0051.
Air of 0·5 atmosphere	409·5 seconds . . .	1·0541.
Air of 0·25 atmosphere	438·5 seconds . . .	1·1287.

It thus appears that the effusion of air into a vacuum is very little affected by a moderate change of density; air of 1 atmosphere and of 0·75 atmosphere passing in nearly the same time. The effect therefore of the ordinary changes of the barometer on the effusion of air must be small, if at all sensible. A retardation occurs in the effusion of air of diminished density, which amounts to an excess of $\frac{1}{200}$th of the time, on air of 0·75 tension; of $\frac{1}{20}$th on air of 0·5 tension, and $\frac{1}{8}$th on air of 0·25 tension.

Experiments were also made on the effusion of air of higher density than 1 atmosphere. The air was drawn of any required tension from 1 to 2 atmospheres from a strong globular vessel A (fig. 3. Plate XXXIII.), provided with a gauge barometer and mercury, by which the tension of the compressed air within it was observed. Before its admission into this vessel the air was previously condensed in another vessel D by a syringe, to a higher degree of density than was required in A, and the supply of compressed air, regulated by the adjustment of an intermediate stopcock, so as to keep the gauge of A at a constant elevation, which could easily be done within $\frac{1}{20}$th of an inch.

In experiments with compressed air, the latter was allowed to flow into the two-pint jar exhausted on the plate of the air-pump, and the time observed which the gauge barometer required to fall through its range from 28 to 2 inches. During the following experiments the height of the barometer was 29·3 inches, which is the value of 1 atmosphere, and the thermometer 53°.

TABLE VI.—Effusion of Air of different Densities.

Height of gauge barom. in inches.	Air of 1 atmosphere.		Air of 1·25 atmosphere.		Air of 1·5 atmosphere.		Air of 1·75 atmosphere.		Air of 2 atmospheres.		Air of 1 atmosphere.	
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	III.	IV.
	″	″	″	″	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0	0	0	0	0
20	116	116	90	91	76	75	65	65	56	55	117	117
12	118	118	92	91	76	76	64	64	56	56	118	118
8	65	65	47	48	38	38	33	33	30	29	66	67
4	79	80	50	50	41	40	33	32	26	28	80	80
2	54	54	26	25	18	18	16	17	14	13	54	53
	432	433	305	305	249	247	211	211	182	181	435	435

In these experiments the depression of the gauge barometer is not produced by a constant volume of the compressed air, but by a volume which is inversely proportional to the density of the compressed air; half a volume of air of 2 atmospheres being equal in the aspirator-jar, on the plate of the air-pump, to a whole volume of air of 1 atmosphere. Correcting the times of the preceding table, we have the passage of *equal volumes* of air of different densities, between the gauge height of 28 and 12 inches, as follows :—

	Time of effusion of equal volumes.	
Air of 1 atmosphere	234·5 seconds	1
Air of 1·25 atmosphere	227·5 seconds	0·9701
Air of 1·5 atmosphere	227·2 seconds	0·9688
Air of 1·75 atmosphere	225·2 seconds	0·9603
Air of 2 atmosphere	223 seconds	0·9510

It appears then that air of different densities between 1 and 2 atmospheres is effused in nearly equal times, the time of effusion diminishing slightly, not more than 5 per cent. with air of double tension. Taking the whole range of the preceding and present results, we have air varying in density from 0·25 to 2 atmospheres, or from 1 to 8, while the extreme variation in the time of the effusion of equal volumes is from 0·9510 to 1·1287, or from 1 to 1·1868.

In the lower part of the scale a more sensible inequality is perceived. Thus, with an exhaustion of from 8 to 4 inches in the aspirator-jar, the passage of equal volumes of air of different densities takes place in the following times :—

	Time of effusion of equal volumes.	
Air of 1 atmosphere	145 seconds	1
Air of 1·25 atmosphere	121·9 seconds	0·8407
Air of 1·5 atmosphere	117·7 seconds	0·8117
Air of 1·75 atmosphere	114·6 seconds	0·7903
Air of 2 atmospheres	113 seconds	0·7793

Here the time of effusion of air of 2 atmospheres falls about 22 per cent. below that of air of 1 atmosphere, while in the upper part of the scale the difference was only 5 per cent.

[8. *Effusion of Air of different Temperatures, by Plate* F.

This plate was a portion of thin platinum foil, with an aperture of an irregular hatchet form, of which the two greatest cross diameters were $\frac{1}{650}$th and $\frac{1}{520}$th of an inch. The perforated plate was attached to the end of the little brass cylinder by means of soft solder. A two-pint jar, giving a cavity of 72·54 cubic inches, was used as the aspirator-jar, and the time of the fall of the gauge barometer was observed from 28·5 to 23·5 inches, with the admission of dry air at different temperatures.

1. The temperature of the room being 41° Fahr., and the height of the barometer 29·616 inches, dry air entered the aspirator-jar in three experiments in 533, 532 and 530 seconds, of which the mean is 531·66 seconds. The room being afterwards heated up to 52°, the time of effusion of an equal volume of air was found to be, in three experiments, 525, 527 and 526 seconds, of which the mean is 526 seconds; or, a rise of 11° in temperature has shortened the time of effusion by 5·66 seconds. Taking the density of air at 32° as 1, at 41° it will be 0·9820, of which the square root is 0·9909; and at 52° it will be 0·9609, of which the square root is 0·9802. Now the relative times of effusion observed, namely, 531·66 and 526 seconds, are as 0·9909 to 0·9803, numbers which all but coincide with the square roots of the densities, 0·9909 and 0·9802, at the two different temperatures.

2. With the barometer at 30·186 to 30·150 inches, experiments were again made on the effusion of the same volume of dry air at 38°, 48° and 58°, four hours elapsing between each set of experiments, which were required to bring up the room and apparatus to a uniform and steady temperature. In three experiments at each temperature,—

The time of effusion at 38° was 526, 527 and 526 seconds: mean 526·33.
The time of effusion at 48° was 520, 521 and 520 seconds: mean 520·33.
The time of effusion at 58° was 515, 516 and 515 seconds: mean 515·33.

Here the first rise of 10° shortens the time of effusion 6 seconds, and the second rise of 10° shortens the time 5 seconds more. The density of dry air being 1 at 32°, it is at 38°, 0·9879; at 48°, 0·9684; and at 58°, 0·9497, of which three last densities the square roots are 0·9939, 0·9841 and 0·9745 respectively. Now the three mean times of effusion observed are in the proportion of the numbers 0·9939, 0·9826 and 0·9731, which correspond more closely with the preceding square roots than could be expected from the nature of the experiments. It appears then that *the effusion time of air of different temperatures is proportional to the square root of its density at each temperature*. The velocity of the effusion will be inversely as the square root of the air's density. Hence two volumes of air which have not the same temperature, are, in regard to effusion, like different gases possessing the densities of the air at the two temperatures.

As the velocity of the effusion of air does not increase at a rate so rapid as the direct proportion of its expansion by heat, it follows that the flow of air under pressure, through a small aperture, is retarded by heating the air; that is, the same absolute quantity or weight of air will take a longer time to pass, when rarefied by heat, than when in a dense state.

I have made several experiments on the influence of *aqueous vapour* upon the effusion of air. When dry air was effused into an aspirator-jar with the gauge barometer attached, and immediately afterwards air saturated with moisture at the same temperature, the latter passed through in sensibly the same time with comparatively large apertures, but in a shorter time with small apertures, although in general without much uniformity in successive experiments. Thus the time for dry air being constant at 524 seconds with plate F of small aperture, barometer 29·812, and thermometer 49°; with moist air, the time gradually fell, till at last it appeared to settle at 506 seconds, that number being obtained in three successive experiments; the temperature in the mean time having risen to 51°. There is here an acceleration of 18 seconds, of which not more than 2 seconds are accounted for by the diminished density of the moist air, and 1 second more by the rise in temperature. The moist air seemed also to have an extraordinary effect in opening and enlarging fissures, and very soon rendered more than one platinum plate useless, which was fixed by brazing, by that action. Nov. 1847.]

Part II.—TRANSPIRATION OF GASES.

1. *Transpiration of Air of different Densities or Elasticities, by a Glass Capillary Tube* E.

(*a*.) The same arrangements were adopted as in the effusion of air of different densities, lately described, the capillary tube being interposed in the place of the perforated plate. The apparatus employed is represented in fig. 4. Plate XXXIII.

With barometer 29·28, and thermometer 54°, 65 cubic inches of dry air of the atmospheric density were transpired from the globular vessel *a* (fig. 2), into a good vacuum sustained by continued pumping, through a capillary glass tube E, twenty feet in length; the same volume of air of 0·75 atmosphere and 0·5 atmosphere, measured at these pressures, were also transpired by the same capillary. The times were as follows:—

	I.	II.	Mean.
Transpiration of air of 1 atmosphere	799″	800″	799″·5
Transpiration of air of 0·75 atmosphere	1049	1051	1050
Transpiration of air of 0·5 atmosphere	1545	1542	1543·5

It is obvious that the times approach the inverse ratio of the tensions, as will appear more clearly on comparing the times observed with those calculated on that principle.

	Time observed.	Time calculated.
Transpiration of air of 1 atmosphere	1	1
Transpiration of air of 0·75 atmosphere	1·3133	1·3333
Transpiration of air of 0·5 atmosphere	1·9306	2

With air of higher tension than 1 atmosphere, the same apparatus for compression was also employed as in the effusion experiments (fig. 3). The capillary E communicated with the two-pint aspirator-jar (capacity 72·54 cubic inches), which was fully exhausted on the plate of the air-pump. The air being then allowed to pass into the capillary, the instant of time was noted when the gauge barometer fell to 28 inches, and the other points described below. The external barometer stood at 29·08 inches; thermometer at 53°.

TABLE VII.—Transpiration of Air of different Densities.

Gauge barometer in inches.	Air of 1 atmosphere.		Air of 2 atmospheres.		Air of 1·75 atmosphere.		Air of 1·5 atmosphere.		Air of 1·25 atmosphere.		Air of 1 atmosphere.
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	III.
	″	″	″	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0	0	0	0
20	253	254	66	67	85	86	114	114	162	161	255
12	310	310	70	69	91	90	123	124	182	179	311
8	220	220	37	37	49	49	69	70	110	109	221
4	349	352	39	40	53	53	78	77	132	134	346
2	328	328	20	19	29	28	41	41	78	79	229
	1460	1464	232	232	305	306	425	426	664	662	1462

The times of transpiration in the preceding table require to be corrected, as they represent the passage of equal volumes of air measured after and not before the transpiration. Thus the same depression of the gauge barometer would be produced by half a volume of air of 2 atmospheres, as by a whole volume of air of 1 atmosphere; and it is necessary therefore to double the times observed of air of the former density, to obtain the time of passage of a whole volume. For the transpiration of equal volumes, in the gauge-range from 28 to 20 inches, which is most nearly equivalent to the action of a vacuum, we have—

Equal volumes.	Observed time of transpiration.		Calculated time.
Air of 1 atmosphere.........	254 seconds.........	1	1
Air of 1·25 atmosphere.........	201·9 seconds.........	0·7949	0·8000
Air of 1·5 atmosphere.........	171 seconds.........	0·6732	0·6666
Air of 1·75 atmosphere.........	149·6 seconds.........	0·5890	0·5714
Air of 2 atmospheres	133 seconds.........	0·5236	0·5

The calculated times of the last column are the reciprocals of the tension, or number of atmospheres in the first column; they represent the observed times within a sufficient degree of approximation, to prove that *for equal volumes of air of different densities, the times of transpiration are inversely as the densities.* The velocity of transpiration will therefore be directly in proportion to the density of the air; air of double density being transpired into a vacuum in half time.

This at once separates the action of a capillary tube from that of a minute aperture; for air of all densities, it will be remembered, passes into a vacuum by effusion with equal velocity.

A consequence of this law immediately appears in conducting transpiration experiments, in the marked influence of the height of the barometer on the time of transpiration; the higher the barometer and the denser the air, the more quickly does a constant volume of it pass through a capillary tube into a vacuum.

This appears also to separate transpiration from the ordinary action of friction, for the denser the air, the more should its passage be retarded by friction.

[2. *Transpiration of Air of different Temperatures.*

Dry air was transpired by a glass capillary tube K, of fine bore, 39·4 inches in length, into a two-pint jar till the gauge barometer fell from 28·5 to 23·5 inches, in 796, 794 and 794 seconds, in three successive experiments, made at the temperature of 41° Fahr., and with the barometer at 30·052 inches. Four hours afterwards, the air and all the apparatus having been for some time at 58°, an equal volume of dry air was transpired twice in 814 seconds. A difference of 17 degrees of temperature has made a difference of 19 seconds in the time of transpiration, and *the dense cold air is transpired most rapidly.* The times are nearly in the inverse ratio of the square root of the densities of air at the two temperatures.

The transpiration of air in the first experiments which are made in the morning is often observed to be more rapid than in those which follow, owing I believe to the low nocturnal temperature being retained for some time by the glass capillary. January, 1847.]

3. *Preliminary Experiments on the Transpiration of different Gases by Capillary Tubes,* A, B *and* C.

The times of transpiration of the gases will be expressed in the sequel with reference to the time of oxygen as unity instead of that of air. Assuming what is now almost universally conceded, that the atomic weights of the following elements are exactly expressed by entire numbers, namely, oxygen by 8, nitrogen by 14, carbon by 6, and hydrogen by 1, and that while the equivalent proportion of the first affords one volume of gas, that of each of the others affords two volumes, we obtain the following theoretical densities for these elements and several of their gaseous compounds. The experimental determinations which appear to be of most value are subjoined.

TABLE of Specific Gravities of Gases.

	Air = 1.		Oxygen = 1 and 16.		
	Calculated.	Observed.	Calculated.		Observed.
Oxygen	1·1099*	1·10563 REGNAULT.	1	16	1
Nitrogen..................	0·9712	0·97137 REGNAULT.	0·8750	14	0·8785 REGNAULT.
Air	1	1	0·9010	14·416	0·9038 REGNAULT.
Hydrogen	0·06937	0·06926 REGNAULT.	0·0625	1	0·0626 REGNAULT.
Carbon	0·4162	....	0·3750	6	
Carbonic acid..	1·5261	1·52901 REGNAULT.	1·3750	22	1·3830 REGNAULT.
Nitrous oxide...........	1·5261	....	1·3750	22	
Nitric oxide	1·0405	....	0·9375	15	
Carbonic oxide	0·9712	0·9678 WREDE.	0·8750	14	0·8754 WREDE.
Carburetted hydrogen	0·5549	0·555 { THOMSON and HENRY. }	0·5000	8	0·5001 { THOMSON and HENRY.
Olefiant gas	0·9712	0·9852 SAUSSURE.	0·8750	14	0·8904 SAUSSURE.
Sulphuretted hydrogen	1·1793	1·1912 { GAY-LUSSAC and THENARD }	1·0625	17	1·0766 { GAY-LUSSAC and THENARD.

With the exception of the recent valuable determinations of M. REGNAULT and Baron WREDE, the calculated specific gravities are probably nearer the truth and more to be depended on than the experimental results found in books, which are old, and generally not made with that degree of precision which the science now requires.

Capillary A.—This glass tube was thirty inches in length, and of a fine cylindrical bore; it allowed 1 cubic inch of air of the usual tension, to pass into a vacuum in about 13 seconds. A pint-jar was exhausted, of which the capacity, including the vacuous spaces of the air-pump, was 41·64 cubic inches. The gas entered into this space, passing through the capillary, and depressed the attached gauge barometer in the times stated in the following Tables:—

TABLE VIII.—Transpiration by Capillary A into a one-pint jar. Barom. 29·55. Temp. 61°.

Gauge barometer in inches.	Air.		Oxygen.		Hydrogen.	
	I.	I.	I.	II.	I.	II.
28	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0
20	150·5	150	166·5	166	71	70·5
12	181·5	182	201	201·5	87	87
4	321	321	354·5	354	156	155
2	....	....	213·5	215·5	94·5	94·5
From 28 to 4 inches	653	653				
From 28 to 2 inches	....	....	935·5	937	408·5	407

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* Assigning the theoretical densities of 14 and 16 to nitrogen and oxygen, and assuming air to be composed of 79·2 volumes of the first, and 20·8 volumes of the second, the density of air will be expressed by the intermediate number 14·416; or, with the density of air = 1, the density of oxygen becomes 1·1099, and the density of nitrogen 0·9711, both as given above. Hydrogen is calculated in the same column as $\frac{1}{16}$th of oxygen (1·1099), carbon as $\frac{6}{16}$ths, carbonic acid and nitrous oxide as each $\frac{22}{16}$ths; nitric oxide as the mean of nitrogen and oxygen, carbonic oxide and olefiant gas as $\frac{14}{16}$ths of oxygen; carburetted hydrogen as $\frac{8}{16}$ths, and sulphuretted hydrogen as $\frac{17}{16}$ths.

Mean Results.

Gauge barometer.		Air.	Hydrogen.
From 28 to 20 inches	Time in seconds	150·25	70·75
	Time of oxygen=1...	0·9037	0·4255
From 20 to 12 inches	Time in seconds	181·75	87
	Time of oxygen=1...	0·9031	0·4322
From 12 to 4 inches	Time in seconds	321	155·5
	Time of oxygen=1...	0·9061	0·4389
From 4 to 2 inches	Time in seconds	....	94·5
	Time of oxygen=1...	....	0·4405
From 28 to 4 inches	Time in seconds	653	313·25
	Time of oxygen=1...	0·9047	0·4340
From 28 to 2 inches	Time in seconds	....	407·75
	Time of oxygen=1...	....	0·4355

Table IX.—Transpiration by Capillary A into a one-pint jar. Barom. 29·5. Temp. 58°·5.

Gauge barometer in inches.	Air.		Oxygen.		Carburetted hydrogen.		Carbonic acid.	
	I.	II.	I.	II.	I.	II.	I.	II.
	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0
20	150	150	166·5	166	94·5	94·5	131	131
12	182·5	182	202	201·5	118·5	119	158	158
4	318·5	318	359·5	357	198·5	198	272	271
2	190·5	192	217	216	119	118	159	159
From 28 to 2 inches	841·5	842	945·5	940·5	530·5	529·5	720	719

Mean Results.

Gauge barometer.		Air.	Carburetted hydrogen.	Carbonic acid.
From 28 to 20 inches	Time in seconds	150	94·5	131
	Time of oxygen=1...	0·9022	0·5684	0·7879
From 20 to 12 inches	Time in seconds	182·25	118·75	158
	Time of oxygen=1...	0·9033	0·5886	0·7831
From 12 to 4 inches	Time in seconds	318·25	198·25	271·5
	Time of oxygen=1...	0·8914	0·5505	0·7600
From 4 to 2 inches	Time in seconds	191·25	118·5	159
	Time of oxygen=1...	0·8833	0·5473	0·7344
From 28 to 2 inches	Time in seconds	841·75	530·	719·5
	Time of oxygen=1...	0·8928	0·5622	0·7633

It will be observed that the proportion between the times of oxygen and air is subject to a variation at different parts of the scale, but is so small as to be within the errors of observation; while this nearly constant ratio of their times coincides almost with that of their specific gravities (1 to 0·9038 Regnault).

The time or rate of hydrogen varies to the extent of 0·015 at different parts of the scale, the passage of that gas being relatively quicker at high than at low pressures.

It is a question how far this variation in the ratio is owing to the action of effusion; the time of effusion of this gas being only 0·25, referred to oxygen as unity, while its time of transpiration is 0·4355. The influence of effusion upon the rate of passage is likely to be most considerable when the pressure is greatest; and that of transpiration, on the contrary, most considerable when the resistance to the passage of the gas is greatest and the pressure least, that is, in the lower part of the scale.

It may be observed that the transpiration time of hydrogen does not differ far from 0·4375, which is one-half of the transpiration time of nitrogen, calculated from the experiment on air, or seven-sixteenths of that of oxygen.

Carbonic acid appears to be much more quickly transpired than oxygen, although denser than that gas in the ratio of 11 to 8; but the effusion time of carbonic acid being slow, any influence of effusion will increase the time of transpiration of this gas,—the reverse of what occurs with hydrogen. The transpiration time of carbonic acid varies considerably at different pressures, being slower by 0·0535 at the upper than the lower part of the scale. An approach to 0·75, or twelve-sixteenths of the time of oxygen, may be noted at present in the rate of this gas.

The transpiration rate of carburetted hydrogen appears to be affected by an error of observation in the middle part of the scale; but its rate is slower at the upper part than at the lower, to the extent of 0·0211. This is also in accordance with the assumed influence of effusion, the effusion time of this gas being greater than its transpiration time. The transpiration time of carburetted hydrogen is not in direct proportion to its gravity, which is 0·5, or one-half of that of oxygen: it approaches more nearly to 0·5625, which is nine-sixteenths of the time of oxygen.

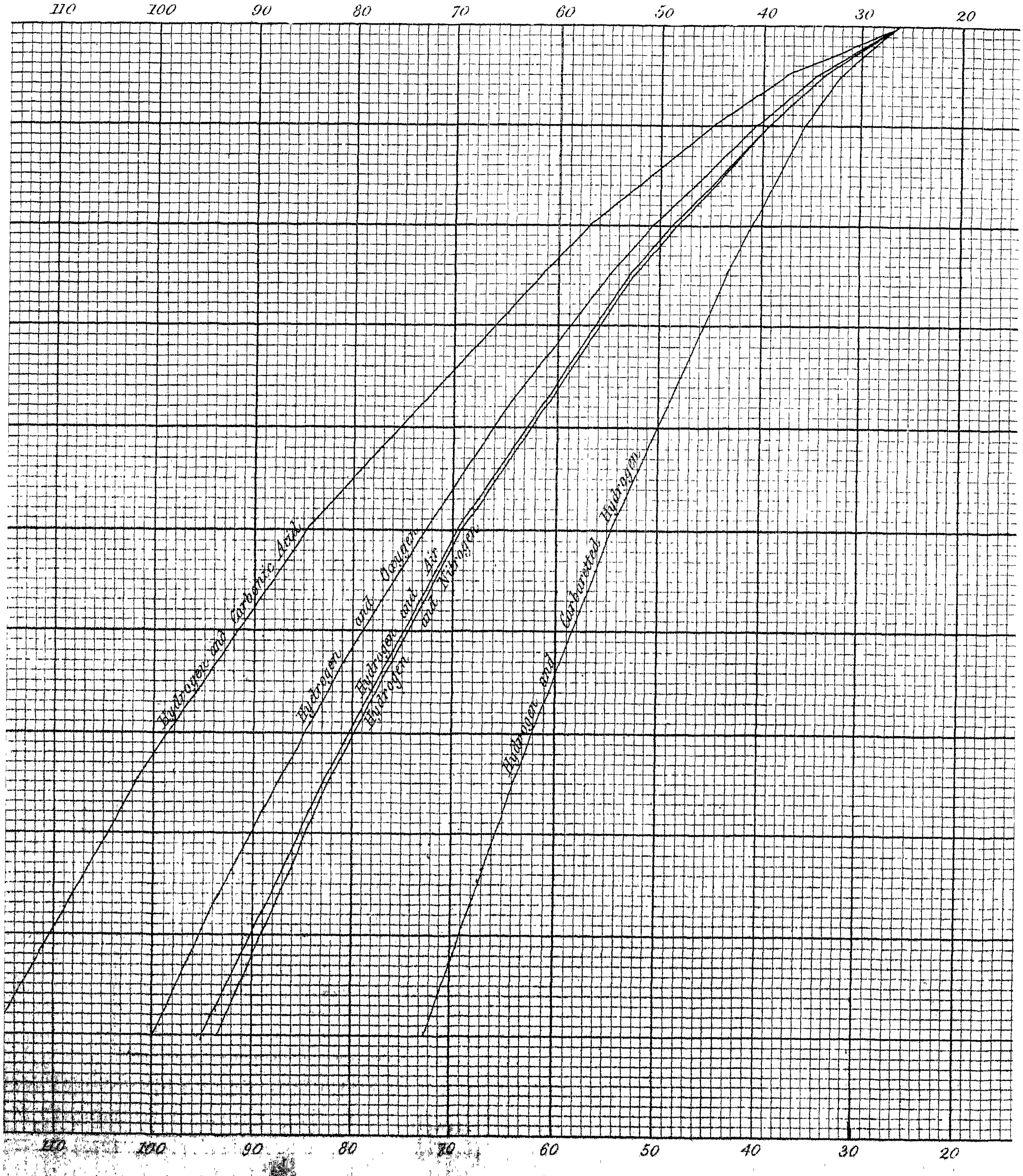
Capillary B.—This glass tube was 31·5 inches in length, of a round bore, but decidedly conical. It was first placed so that the gas entered the tube by the large and escaped by the small opening. When so arranged this tube allowed 1 cubic inch of air to pass into a vacuum in 34·3 seconds, or the transpiration was nearly three times slower than by A.

Table X.—Transpiration by Capillary B into a half-pint jar (21·26 cubic inches). Barom. 29·17. Temp. 68°.

Gauge barometer in inches.	Oxygen.		Nitrogen.			Carburetted hydrogen.	
	I.	II.	I.	II.	III.	I.	II.
	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0
20	235·5	235·5	209	205	205	133	133
12	289	290·5	252	253	......	162·5	163
4	521	521	451·5	453·5	......	290·5	290·5
2	290·5	290	258	255·5	......	164	165·5
From 28 to 2 inches ...	1336	1337	1170·5	1167	205	750	752

Phil. Trans MDCCCXLVI. Plate

Effusion of mixed Gases.



Mean Results.

Gauge barometer.		Nitrogen.	Carburetted hydrogen.
From 28 to 20 inches	Time in seconds	206·3	133
	Time of oxygen=1...	0·8760	0·5647
From 20 to 12 inches	Time in seconds	252·5	162·7
	Time of oxygen=1...	0·8716	0·5618
From 12 to 4 inches	Time in seconds	452·5	290·5
	Time of oxygen=1...	0·8685	0·5576
From 4 to 2 inches...	Time in seconds	256·7	164·7
	Time of oxygen=1...	0·8845	0·5677
From 28 to 2 inches	Time in seconds	1168·7	751
	Time of oxygen=1...	0·8740	0·5619

Table XI.—Transpiration by Capillary B into a half-pint jar. Barom. 29·2.

Gauge barometer in inches.	Oxygen.			Hydrogen.			Carbonic acid.		
	I.	II.	III.	I.	II.	III.	I.	II.	III.
	62°	62°·5	64°·5	65°	65°	65°·5	66°	66°	66°
28	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	234	234	234·5	103	103	103	174·5	174	173
12	285	287·5	288·5	126·5	126	126·5	212	211·5	212
4	516	516	516·5	229·5	228	228	376	379·5	376
2	290	292·5	288·5	129	126	132	....	213	212·5
	62°·5	64°	64°·5	65°	65°·5	....	....	66°	66°
From 28 to 2 inches ...	1325	1330	1328	588	583	589·5	....	978	974

Mean Results.

Gauge barometer.		Hydrogen.	Carbonic acid.
From 28 to 20 inches	Time in seconds	103	173·8
	Time of oxygen=1......	0·4398	0·7424
From 20 to 12 inches	Time in seconds	126·3	211·8
	Time of oxygen=1......	0·4403	0·7385
From 12 to 4 inches	Time in seconds	228·5	377·3
	Time of oxygen=1......	0·4425	0·7310
From 4 to 2 inches...	Time in seconds	129	212·75
	Time of oxygen=1......	0·4443	0·7327
From 28 to 2 inches	Time in seconds	586·8	976
	Time of oxygen=1......	0·4413	0·7351

Taking the higher part of the scale, from 28 to 20 inches, which approaches nearest to transpiration into a vacuum, we obtain the following times of transpiration:—Oxygen 1, nitrogen 0·8760, hydrogen 0·4398, carburetted hydrogen 0·5647, carbonic acid 0·7424; which almost coincide with the numbers lately mentioned in relation to these gases, with the exception of carbonic acid, which is 0·7424 instead of 0·75. With the great resistance of this tube, the variation in ratio at different parts of the scale has also become very small, being only 0·0045 for hydrogen and 0·0097 for carbonic acid. The disturbing influence of effusion appears therefore to be in a great measure eliminated. It is also worthy of remark, that the time of passage of carbonic acid into a perfect vacuum would certainly approach still more nearly to 0·75; for the rate of transpiration of that gas appears, in the case of the present capillary, to become slower with the increase of pressure. It will be seen hereafter that the gases deviate very sensibly at low pressures from the empirical coefficients of transpiration which have been named, becoming slower in their passage with reference to oxygen, as is here observed of carbonic acid. This deviation appears to be connected with excessive resistance, whether arising from the smallness of the capillary opening or diminished pressure.

With the view of observing the effect of alterations in the position and dimensions of a capillary, experiments were now made with this tube, (1) in an inverted position, so that the gas entered by the narrow and escaped by the wide end, and (2) after being reduced to half its original length.

Capillary B *reversed.*—The passage of gas through this tube was nearly three times more rapid in the new direction, 1 cubic inch of air being now transpired into a vacuum in 12·6 seconds. The length of the tube and resistance to passage through it are therefore nearly the same as in capillary A; but while the latter was of uniform bore, the present capillary is highly conical.

TABLE XII.—Transpiration by Capillary B reversed into a one-pint jar. Barom. 30·13.

Gauge barometer in inches.	Air.			Oxygen.			Hydrogen.		Carbonic acid.		
	I.	II.	III.	I.	II.	III.	I.	II.	I.	II.	III.
	59° F.	59° F.	59° F.	61° F.			61°·5F.	61°·5F.	62° F.	62° F.	
28	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	149·5	144·5	145	160	160	160	69	69	127	126	126
12	173·5	177·5	178	198	196	196	86	85·5	154	153	152
4	318	318	317	352·5	353·5	353·5	157·5	157·5	268·5	267·5	268·5
2	190	189·5	192·5	216	216·5	215	96	96·5	154·5	155	156·5
From 28 to 12 inches...	323	322	323	358	356	356	155	154·5	281	279	278
From 28 to 2 inches...	831	829·5	832·5	926·5	926	924·5	408·5	408·5	704	701·5	703

Mean Results.

Gauge barometer.		Air.	Hydrogen.	Carbonic acid.
From 28 to 12 inches	Time in seconds	322	154·75	279·33
	Time of oxygen=1...	0·9024	0·4338	0·7831
From 12 to 4 inches	Time in seconds	317·7	157·5	268·16
	Time of oxygen=1...	0·8994	0·4459	0·7595
From 4 to 2 inches	Time in seconds	190·7	96·25	155·33
	Time of oxygen=1...	0·8836	0·4459	0·7197
From 28 to 2 inches	Time in seconds	831	408·5	702·83
	Time of oxygen=1...	0·8978	0·4413	0·7594

The coefficients of air and hydrogen, although still corresponding very closely with the numbers 0·9038 and 0·4375, begin to exhibit a sensible variation in different parts of the scale. The variation in carbonic acid is considerable, amounting to 0·0634, and the divergence is on both sides of the empirical number 0·75.

Capillary B *shortened.*—The tube was preserved in its last position, but its length reduced to 14·5 inches. It now allowed 1 cubic inch of air to pass into a vacuum in 6·4 seconds; or twice as rapidly as when entire.

TABLE XIII.—Transpiration by Capillary B ($14\frac{1}{2}$ inches long) into a one-pint jar. Barom. 30·12.

Gauge barometer in inches.	Air.			Oxygen.			Nitrogen.		Carburetted hydrogen.			Hydrogen.			Carbonic acid.	
	I.	II.	III.	I.	II.	III.	I.	II.	I.	II.	III.	I.	II.	III.	I.	II.
				62° F.	62° F.	62° F.	63° F.	63° F.	62° F.	61° F.	62° F.	62° F.	62° F.	62° F.	62° F.	62° F.
28	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	75	75	75·5	82·5	83·5	82	72	72	48	48	48	34·5	34	34	69	69
12	89·5	89·5	89·5	99·5	99·5	100	87·5	88	57	57	57	41·5	41·5	41·5	81	80·5
4	158	157	157·5	175	175·5	174·5	152·5	152·5	98	98	98	75	75	75	137·5	136·5
2	91·5	91	92	102	103	102·5	91	89·5	56	56	55·5	45·5	45·5	45	77	77·5
From 28 to 12 in.	164·5	164·5	164·5	182	183	182	159·5	160	105	105	105	76	75·5	75·5	150	149·5
From 28 to 2 in.	414	412·5	414·5	459	461·5	459	403	402	259	259	258·5	196·5	196	195·5	364	363·5

Mean Results.

Gauge barometer.		Air.	Nitrogen.	Carburetted hydrogen.	Hydrogen.	Carbonic acid.
From 28 to 12 inches	Time in seconds	164·5	159·75	105	75·66	149·7
	Time of oxygen=1...	0·9023	0·8763	0·5728	0·4150	0·8211
From 12 to 4 inches	Time in seconds	157·5	152·5	98	75	137
	Time of oxygen=1...	0·9000	0·8714	0·5600	0·4285	0·7828
From 4 to 2 inches	Time in seconds	91·5	90·25	55·83	45·33	77·25
	Time of oxygen=1...	0·8926	0·8804	0·5447	0·4325	0·7546
From 28 to 2 inches	Time in seconds	413·7	402·5	258·83	196	363·75
	Time of oxygen=1...	0·8999	0·8755	0·5632	0·4263	0·7912

The times are now too short for accurate numerical determinations, but it is obvious that while the relative times of air and nitrogen are little changed, particularly from 28 to 4 inches, the times of hydrogen and carbonic acid are sensibly affected by effusion, and most so in the upper part of the scale; the coefficient of hydrogen falling to 0·4150, while that of carbonic acid rises to 0·8211. From 4 to 2 inches, the rates are 0·4325 and 0·7546; numbers which still diverge a little from the empirical coefficients, but both in the direction of the effusion influence.

Reduced to 7 inches in length and now allowing 1 cubic inch of air to pass into a vacuum in 3·4 seconds, this capillary was found to be still less adapted for transpiration. In a series of observations, which are not of sufficient importance to be particularly detailed, the coefficients of the gases in the range from 28 to 12 inches, were,—air 0·9194, nitrogen 0·8983, carburetted hydrogen 0·6029, carbonic acid 0·9028, and hydrogen 0·3930: numbers which demonstrate an increasing interference of effusion. In the range from 12 to 4 inches, the coefficients were,—air 0·9114, nitrogen 0·8851, carburetted hydrogen 0·5764, carbonic acid 0·8303, hydrogen 0·4180.

Of this last portion of capillary B, 6·5 inches were found to contain 2·78 grains of mercury, which gives the tube a mean diameter of 0·0137, or $\frac{1}{73}$rd of an inch.

Capillary C.—This was a tube of exceedingly fine bore; 8·3 inches of the tube containing only 0·65 grain of mercury; which gives a diameter of 0·00539 inch, or about $\frac{1}{186}$th of an inch. Experiments were made with portions of this tube of different lengths; and first with a portion only 1 inch in length, in which it was expected that the influence of effusion would be considerable, from its approach to an aperture in a thin plate.

TABLE XIV.—Transpiration by Capillary C (1 inch long) into a one-pint jar.
Barom. 28·81. Temp. 60°.

Gauge barometer in inches.	Air.		Oxygen.		Hydrogen.		Carbonic acid.
	I.	II.	I.	II.	I.	II.	I.
28	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0
20	248·5	249	273	271·5	108	108	237·5
12	283	281·5	308·5	308·5	126	127	261
8	186·5	185·5	204·5	206	87	87	167
4	284	286	315·5	314	136	137	244
2	270·5	266·5	301	302	133	132	227
From 28 to 2 inches......	1272·5	1268·5	1402·5	1402	590	591	1136·5

Mean Results.

Gauge barometer.		Air.	Hydrogen.	Carbonic acid.
From 28 to 20 inches	Time in seconds	248·75	108	237·5
	Time of oxygen=1...	0·9138	0·3967	0·8725
From 28 to 12 inches	Time in seconds	531	234·75	498·5
	Time of oxygen=1...	0·9139	0·4040	0·8594
From 20 to 12 inches	Time in seconds	282·25	126·5	261
	Time of oxygen=1...	0·9149	0·4100	0·8460
From 12 to 8 inches	Time in seconds	186	87	167
	Time of oxygen=1...	0·9063	0·4238	0·8138
From 8 to 4 inches	Time in seconds	285	136·5	244
	Time of oxygen=1...	0·9054	0·4339	0·7751
From 4 to 2 inches	Time in seconds	268·5	132·5	227
	Time of oxygen=1...	0·8905	0·4374	0·7529
From 28 to 2 inches	Time in seconds	1270·5	590·5	1136·5
	Time of oxygen=1...	0·9060	0·4211	0·8104

TABLE XV.—Transpiration by Capillary C (2 inches long) into a half-pint jar.
Barom. 29·32.

Gauge barometer in inches.	Air.		Oxygen.		Hydrogen.	
	I.	II.	I.	II.	I.	II.
28	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0
20	211·5	211·5	234	234	101·5	102
12	254	254	281·5	281	124·5	124
8	176·5	176·5	196	197	88	88
4	280·5	280·5	321·5	320	141·5	138
2	273	272	301	302	141	146
From 28 to 2 inches......	1195·5	1196	1334	1334	596·5	598

Mean Results.

Gauge barometer.		Air.	Hydrogen.
From 28 to 20 inches	Time in seconds	211·5	101·75
	Time of oxygen=1...	0·9038	0·4348
From 20 to 12 inches	Time in seconds	254	124·25
	Time of oxygen=1...	0·9031	0·4417
From 12 to 8 inches	Time in seconds	176·5	88
	Time of oxygen=1...	0·8981	0·4478
From 8 to 4 inches	Time in seconds	281·25	139·75
	Time of oxygen=1...	0·8768	0·4357
From 4 to 2 inches	Time in seconds	272·5	143·52
	Time of oxygen=1...	0·9038	0·4759
From 28 to 2 inches	Time in seconds	1195·75	597·25
	Time of oxygen=1...	0·8964	0·4476

TABLE XVI.—Transpiration by Capillary C (4 inches long) into a half-pint jar.

Gauge barometer in inches.	Air. I.		Air. II.		Oxygen. I.	
	65°		65°		65°	
28	″		0″		0″	
24	205	419	205	419	228	467
20	214		212		239	
16	234	510	236	510	262	575
12	276		278		313	
10	166	361	163	360	183	403
8	195		197		220	
6	248	570	245	580	273	648
5	145		151		169	
4	177		184		206	
3	241	573	238	568	265	659
2	332		330		394	
From 28 to 2 inches......	2433		2439		2752	

Mean Results.

Gauge barometer.		Air.
From 28 to 24 inches	Time in seconds	205
	Time of oxygen=1...	0·8991
From 28 to 20 inches	Time in seconds	418
	Time of oxygen=1...	0·8951
From 20 to 12 inches	Time in seconds	512
	Time of oxygen=1...	0·8904
From 12 to 8 inches	Time in seconds	360·5
	Time of oxygen=1...	0·8945
From 8 to 4 inches	Time in seconds	575
	Time of oxygen=1...	0·8657
From 4 to 2 inches	Time in seconds	570·5
	Time of oxygen=1...	0·8657
From 28 to 2 inches	Time in seconds	2436
	Time of oxygen=1...	0·8852

The velocity with which air passed into a vacuum was, by C 1 inch, 1 cubic inch in 21·26 seconds; by C 2 inches, 1 cubic inch in 35·43 seconds; and by C 4 inches, 1 cubic inch in 70 seconds.

C 1 inch exhibits (Table XIV.) great variation in its rate of transpiration at different pressures, as was to be expected. At the head of the scale, the rate of air is 0·9138, of hydrogen 0·3967, and of carbonic acid 0·8725; which all indicate a great interference of effusion. At the bottom of the scale, on the other hand, where the pressure is small and the resistance to passage consequently great, the rate of air is 0·8905, of hydrogen 0·4374, and of carbonic acid 0·7529, or nearly normal.

With C 2 inches (Table XV.), the rates of air are pretty uniform at different parts of the scale, and sufficiently normal; the deviation from 8 to 4 inches appears to be an accidental anomaly. The rate of hydrogen also is never distant from 0·4375, except at the very bottom of the scale. This appears to be the length of a tube of so small a bore which gives the most uniform results at different pressures:

For with C 4 inches (Table XVI.), where the resistance is excessive, air has a rate corresponding sufficiently with its specific gravity at the head of the scale, but diverging rapidly in the lower part of the scale, the time of transpiration becoming rapid as compared to that of oxygen. With a tube then like the present, the relation between the times of transpiration is only to be looked for within a limited range, and that at a high degree of pressure approaching to a whole atmosphere.

4. *Transpiration by Capillary Tube* H.

As the existence of any simple numerical relation among the gases, such as the preceding experiments on transpiration render probable, would be a point of fundamental importance in their history, I was induced to try new capillary tubes and to multiply experiments, varying the circumstances in which they were made, and taking additional precautions against the interference of disturbing causes. The arbitrary nature of the coefficients of transpiration indeed produces a more than usual necessity for strong evidence and numerous confirmations, as the numbers themselves have no *a priori* probability in their favour.

It appeared desirable to try capillary tubes of larger diameter than those already employed, and of great length; partly to vary the conditions of the experiment, and partly because extreme shortness of tube appears, in the experiments made with C, to be unfavourable to uniformity of rate at different pressures.

Several portions of capillary tube, of which the bore was as nearly equal as could be judged of by the eye, were accordingly selected and cemented together at the blowpipe, so as to form a continuous tube 22 feet in length, which was bent up into coils for convenience in using it, as represented in figure 4, Plate XXXIII. The extremities of this capillary were connected with the block-tin tubes proceeding from the drying tube and air-pump jar respectively, by means of thick caoutchouc adopters, which diminished the rigidity of the arrangement, and protected the glass tube from the effect of the shocks, which are unavoidable in working the air-pump. This capillary (H) allowed 1 cubic inch of air to pass into a vacuum in 15·64 seconds. Two inches of the tube were found to hold 2·65 grains of mercury, which gives a diameter of 0·0222 inch, or $\frac{1}{45}$th of an inch. The tube, however, may have been more contracted at the bendings.

Air-pump jars of greater size were also employed, so as to protract the time of passage, and give larger numbers. Of these vessels, which I have termed aspirator jars, the capacity of the "three-pint jar" was 103·56 cubic inches, and that of the "six-pint jar" 201·78 cubic inches; the vacuous channels of the air-pump and connecting tubes being included in these measurements.

The temperatures recorded are those of the interior of the aspirator jar, observed by a very small mercurial thermometer, containing no more than 50 or 60 grains of mercury, and therefore highly sensitive. It will be remarked that the temperature within the receiver always rises, and in general about half of a degree FAHRENHEIT during the continuance of an experiment: this is owing to the compression of the gas already in the receiver by that which enters. The change of temperature due to this cause becomes less considerable with large aspirator jars, which are preferable to small jars for this and other reasons.

As it appears that the relation between the coefficients of transpiration is only to be looked for at high pressures, attention should be more directed to the rates of transpiration in the upper than in the lower part of the scale. The inquiry will therefore be directed with the view of solving the question, What are the coefficients of transpiration of the different gases into a vacuum, or under considerable pressures?

TABLE XVII.—Transpiration by Capillary H. into a three-pint jar. Barom. 30·324.

Gauge barometer in inches.	Air.		Oxygen.		Hydrogen.		Hyd. 95+5 air.		Carbonic acid.	
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5
28	0″	0″	0″	0″	0′	0′	0″	0″	0″	0″
24	213	213	236	237	104	104	125	124	178	177
20	227	227	254	253	111	111	132	132	188	188
12	549	549	611	611	268	269	321	321	454	455
8	389	388	435	435	192	192	227	227	321	320
	61°·75	61°·75	61°·75	61°·75	61°·75	61°·75	61°·75	61°·75	61°·75	61°·75
From 28 to 8 inches......	1378	1377	1536	1536	675	676	805	804	1141	1140

Mean Results.

Gauge barometer.		Air.	Hydrogen.	95 Hyd.+5 air.	Carbonic acid.
From 28 to 24 inches	Time in seconds	213	104	124·5	177·5
	Time of oxygen=1...	0·9006	0·4397	0·5264	0·7505
From 24 to 20 inches	Time in seconds	227	111	132	188
	Time of oxygen=1...	0·8954	0·4378	0·5206	0·7416
From 20 to 12 inches	Time in seconds	549	268·5	321	454·5
	Time of oxygen=1...	0·8985	0·4394	0·5252	0·7438
From 12 to 8 inches	Time in seconds	388·5	192	227	320·5
	Time of oxygen=1...	0·8931	0·4413	0·5218	0·7368
From 28 to 8 inches	Time in seconds	1377·5	675·5	864·5	1140·5
	Time of oxygen=1	0·8968	0·4397	0·5237	0·7425

The numbers for air, hydrogen and carbonic acid accord well with those obtained by the other capillaries. The small addition of 5 per cent. of air to hydrogen has a surprising effect in retarding the transpiration of that gas. The mean rate of such a mixture, calculated from the rates of air and hydrogen separately, is 0·4625, whereas the actual rate is 0·5264. The rate of the mixture should only be increased by 0·0228, whereas it is really increased by 0·0840. Hence the effect of 5 per cent. of air in retarding the rate of hydrogen is nearly four times greater than it should be by calculation. The experiment shows the effect which a small amount of impurity must have in deranging the transpiration rate of that gas. I shall return again to this point under the subject of the transpiration of mixed gases.

Table XVIII.—Transpiration by Capillary H into a three-pint jar.
Barom. 30·3—30·242.

Gauge barometer in inches.	Oxygen.		Nitrogen.		Carbonic oxide.		Air.	
	I.	II.	I.	II.	I.	II.	I.	II.
	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5	61°·5
28	0″	0′	0″	0″	0″	0″	0″	0′
24	238	239	208	208	207	207	214	214
20	253	253	220	221	220	220	229	229
12	614	614	536	533	532	533	552	550
8	434	434	378	376	376	377	389	392
	61°·75	61°·75	62°	62°	62°	62°	62°	62°
From 28 to 8 inches	1539	1540	1342	1339	1335	1337	1384	1385

Mean Results.

Gauge barometer.		Nitrogen.	Carbonic oxide.	Air.
From 28 to 24 inches	Time in seconds	208	207	214
	Time of oxygen=1...	0·8721	0·8679	0·8972
From 24 to 20 inches	Time in seconds	220·5	220	229
	Time of oxygen=1...	0·8715	0·8695	0·9051
From 20 to 12 inches	Time in seconds	534·5	532·5	551
	Time of oxygen=1...	0·8705	0·8673	0·8974
From 12 to 8 inches	Time in seconds	377·5	376·5	390·5
	Time of oxygen=1...	0·8698	0·8675	0·8998
From 28 to 8 inches	Time in seconds	1340·5	1336	1384·5
	Time of oxygen=1...	0·8707	0·8678	0·8993

In the preceding table, a comparison is made between two gases, nitrogen and carbonic oxide, of which the theoretical specific gravities are the same, namely 0·8750, while the mean rate of nitrogen, from 28 to 12 inches, proves to be 0·8707, and that of carbonic oxide 0·8678, which is a pretty close approximation. In several other experiments with these gases, a slight difference in their coefficients of transpiration was observed, carbonic oxide having always the smaller number: the difference generally approached 0·0040. It is not at all impossible, however, that these gases may really differ quite as much in specific gravity; the specific gravity of carbonic oxide found by **Wrede** being 0·8754, on the oxygen scale, while that of nitrogen by **Regnault** is 0·8785.

Table XIX.—Transpiration by Capillary H into a three-pint jar. Barom. 30·232.

Gauge barometer in inches.	Air.		Oxygen.		Carburetted hydrogen.	
	I.	II.	I.	II.	I.	II.
	65°·25	65°·25	66°	66°	66°	66°
28	0″	0″	0″	0″	0″	0″
24	215	216	239	240	131	131
20	229	230	255	256	141	141
12	555	553	617	616	338	338
8	393	393	439	437	240	240
	66°	66°	66°	66°	66°·25	66°·25
From 28 to 8 inches......	1392	1392	1550	1549	850	850

Mean Results.

Gauge barometer.		Air.	Carburetted hydrogen.
From 28 to 24 inches	Time in seconds	215·5	131
	Time of oxygen=1...	0·8997	0·5474
From 24 to 20 inches	Time in seconds	229·5	141
	Time of oxygen=1...	0·8982	0·5518
From 20 to 12 inches	Time in seconds	554	338
	Time of oxygen=1...	0·8986	0·5482
From 12 to 8 inches	Time in seconds	393	240
	Time of oxygen=1...	0·8972	0·5479
From 28 to 8 inches	Time in seconds	1392	850
	Time of oxygen=1...	0·8983	0·5485

Table XX.—Transpiration by Capillary H into a six-pint jar.
Barom. 30·196—30·174.

Gauge barometer in inches.	Oxygen.		Carburetted hydrogen.		Hydrogen.		Air.	
	I.	II.	I.	II.	I.	II.	I.	II.
	66°·75	66°·75	66°·75	66°·75	66°·75	66°·75	67°	67°
28·5	0″	0″	0″	0″	0″	0″	0″	0″
26·5	228	232	126	128	102	101	207	204
24·5	235	233	130	128	102	104	212	211
23·5	121	121	66	67	54	54	108	110
	67°	67°	67°	67°	67°	67°	67°	67°
From 28·5 to 23·5 inches...	584	586	322	323	258	259	527	525

Mean Results.

Gauge barometer.		Carburetted hydrogen.	Hydrogen.	Air.
From 28·5 to 23·5 inches	Time in seconds	322·5	258·5	526
	Time of oxygen=1...	0·5512	0·4418	0·8991

Tables XIX. and XX. exhibit the transpiration rates of carburetted hydrogen and hydrogen, the former of which approaches to 0·55, which is certainly a sensible deviation from 0·5625. The number for hydrogen (0·4418), on the other hand, is but very little removed from 0·4375.

TABLE XXI.—Transpiration by Capillary H into a six-pint jar.
Barom. 30·158—30·138.

Gauge barometer in inches.	Oxygen.		Carbonic oxide.			Nitrogen.		Nitrous oxide.		Carbonic acid.	
	I.	II.	I.	II.	III.	I.	II.	I.	II.	I.	II.
	67°	67°	67°	67°	67°	67°·75	67°·75	68°	68°	68°	68°
28·5	0′	0″	0′	0′	0′	0	0	0′	0′	0′	0″
26·5	230	231	202	200	201	202	202	173	173	173	173
24·5	237	235	202	203	204	205	205	176	175	174	176
23·5	121	121	107	107	106	108	108	91	91	92	92
	67°	67°	67°·25	67°·25	67°·25	68°	68°	68°	68°	68°	68°
From 28·5 to 23·5 inches	588	587	511	510	511	515	515	440	439	439	441

Mean Results.

Gauge barometer.		Carbonic oxide.	Nitrogen.	Nitrous oxide.	Carbonic acid.
From 28·5 to 23·5 inches	Time in seconds	510·5	515·	439·5	440
	Time of oxygen=1...	0·8689	0·8766	0·7480	0·7455

In the preceding table carbonic oxide and nitrogen are again compared, and also another remarkable pair of gases having the same theoretical density, namely carbonic acid and nitrous oxide. The two latter exhibit an extraordinary parallelism in their rates of transpiration in all experiments which were made upon them, provided due attention was paid to the purity of the nitrous oxide. The solution of nitrate of ammonia should always be *filtered*, and the salt crystallized, as the presence of a very minute quantity of solid matter may cause a change in the mode of decomposition of the salt by heat, and the evolution of a very sensible quantity of free nitrogen.

The carbonic oxide of experiments 1 and 2 was obtained by the action of oil of vitriol on pure oxalic acid; that of experiment 3 was prepared by the process of Mr. FOWNES, namely heating oil of vitriol upon the ferrocyanide of potassium, avoiding a violent reaction by a proper regulation of the temperature. The gas of both processes was washed with alkali, although this precaution is scarcely required with the gas of the last process. The transpiration results are exactly the same with the gas prepared in both ways.

TABLE XXII.—Transpiration by Capillary H (with cupped ends) into a six-pint jar. Barom. 29·39. Temp. 51°.

Gauge barometer in inches.	Nitrogen.		Oxygen.		Olefiant gas.		Air.		Carburetted hydrogen.			
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	III.	IV.
28·5	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
26·5	203	204	233	235	122	121	211	211	129	129	129	129
24·5	206	207	236	236	122	122	212	212	129	131	130	130
23·5	104	104	121	120	62	63	108	108	67	66	66	66
From 28·5 to 23·5 inches	513	515	590	591	306	306	531	531	325	326	325	325

Mean Results.

Gauge barometer.		Nitrogen.	Olefiant gas.	Air.	Carburetted hydrogen.
From 28·5 to 23·5 inches.	Time in seconds ...	514	306	531	325·25
	Time of oxygen=1	0·8704	0·5182	0·9000	0·5512

For the experiments of the preceding table the form of the capillary H was so far altered, that a funnel-form was given to the apertures of the tube. This was done by softening the tube in the blowpipe flame, within an inch of each extremity, and expanding the bore into a small ball of about one tenth of an inch in diameter; the ball was afterwards cut across the middle, and left the tube of course with a cup-shaped termination. This change in the condition of the capillary seems to have no effect on the comparative rates of transpiration of the different gases.

It was found that the passage of air became a little slower by cupping the end of the tube by which the gas obtains ingress, in the proportion of 509 to 496; but cupping the point of egress occasioned no further change in the rate, the experiments being made within the pressures of 28·5 and 23·5 inches.

The transpiration rate of olefiant gas differs entirely from that of nitrogen and carbonic oxide, of which gases it possesses the theoretical specific gravity, and is a great deal more rapid; the transpiration coefficient being so low as 0·5182. The specific gravity of the gas made use of was found to be 0·9840, and it was absorbed by the perchloride of antimony to the extent of 96·5 per cent. The determination of the true coefficient for this gas is attended with unusual difficulty, from its constant and I believe unavoidable impurity, as prepared by the action of sulphuric acid upon alcohol.

Table XXIII.—Transpiration by Capillary H (with cupped ends) into a six-pint jar. Barom. 29·91. Temp. 54°.

Gauge barometer in inches.	Air.		Oxygen.		Hydrogen.		Carburet. hyd.		Carbonic oxide.		Carbonic acid.	
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
	″	″	″	″	″	″	″	″	″	″	″	″
28·5	0	0	0	0	0	0	0	0	0	0	0	0
26·5	212	212	234	233	105	105	133	133	206	204	175	176
24·5	212	212	235	236	105	106	134	132	204	205	176	174
23·5	108	107	121	119	53	53	66	67	106	106	90	90
From 28·5 to 23·5 inches	532	531	590	588	263	264	333	332	516	515	441	440

Mean Results.

Gauge barometer.		Air.	Hydrogen.	Carburetted hydrogen.	Carbonic oxide.	Carbonic acid.
From 28·5 to 23·5 inches	Time in seconds ...	531·5	263·5	332·5	515·5	440·5
	Time of oxygen=1	0·9024	0·4473	0·5645	0·8752	0·7479

The results of the preceding table are remarkable as approaching more closely to the empirical numbers than any preceding results obtained by the same capillary. The same observation applies to the results of the table which immediately follows. In the one table, the number for carbonic oxide is 0·8732, in the other 0·8752; the numbers for carbonic acid are 0·7479 and 0·7466; and for carburetted hydrogen 0·5645.

Table XXIV.—Transpiration by Capillary H into a 6-pint jar. Barom. 29·63. Temp. 55°.

Gauge barometer in inches.	Air.		Oxygen.		Carbonic oxide.			Carbonic acid.	
	I.	II.	I.	II.	I.	II.	III.	I.	II.
	″	″	″	″	″	″	″	″	″
28·5	0	0	0	0	0	0	0	0	0
26·5	212	212	236	235	214	214	213	175	176
24·5	214	214	237	239	203	205	205	178	177
23·5	110	110	121	120	100	101	101	90	91
From 28·5 to 23·5 inches	536	536	594	594	517	520	519	443	444

Mean Results.

Gauge barometer.		Air.	Carbonic oxide.	Carbonic acid.
From 28·5 to 23·5 inches	Time in seconds ...	536	518·7	443·5
	Time of oxygen=1	0·9023	0·8732	0·7466

5. *Transpiration of different Gases by a Capillary Tube of Copper.*

It appeared desirable to have experiments on the passage of gases through tubes of different materials, in order to ascertain how far the coefficients of transpiration observed are peculiar to glass. After some trials, a capillary tube of copper was constructed, of a fine smooth bore, not wider than an ordinary thermometer tube, and indeed less in diameter than the preceding glass capillary H. This tube was formed by first drilling a cylindrical hole in the axis of a solid copper rod, 4 or 5 inches in length, and extending the latter afterwards by drawing it through a wire-plate. An iron wire, or triplet, was placed within the copper tube and drawn through the wire-plate at the same time, in order to keep the interior surface of the copper tube smooth and uniform. It was necessary to pull out the iron-wire always after the copper was drawn through the plate, to prevent the former being fixed. The iron-wire was then extended somewhat separately, and again introduced into the copper tube, and the operation of drawing out the latter repeated. In this way the copper tube was extended to a length of 11 feet 8 inches. It was found to be perfectly sound and air-tight; and allowed 1 cubic inch of air to pass into a vacuum in 22·12 seconds. Of the iron wire, upon which the copper tube was last drnwn, 92·7 inches weighed 18·30 grains; or 1 inch 0·1974 grain. Taking the specific gravity of iron at 7·7, this gives as the diameter of the copper tube 0·0114 inch, or $\frac{1}{88}$th of an inch. When used as a transpiration tube it was coiled up into circles of about 10 inches in diameter, and the ends joined by soldering to two block-tin tubes provided with screws by which they could be attached to the aspirator-jar and drying tube.

The experiments were conducted precisely in the same way as with a glass tube, except that oil of vitriol was avoided and chloride of calcium only used in the drying tube. The following series of results were obtained with the copper capillary.

Table XXV.—Transpiration by a Copper Capillary Tube into a one-pint jar. Barom. 29·97. Temp. 58°.

Gauge barometer in inches.	Air.		Oxygen.		Nitrous oxide.		Carbonic acid.		Air.
	I.	II.	I.	II.	I.	II.	I.	II.	I.
28	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	234	233	260	261	198	198	199	199	234
12	291	292	324	324	244	244	245	245	292
8	206	205	228	228	170	170	171	170	204
4	333	335	372	373	275	277	276	276	336
2	342	344	387	390	283	285	287	288	344
From 28 to 4 inches ...	1064	1065	1184	1186	887	889	891	890	1066

Mean Results.

Gauge barometer.		Air.	Nitrous oxide.	Carbonic acid.
From 28 to 20 inches...	Time in seconds	233·5	198	199
	Time of oxygen=1...	0·8963	0·7601	0·7639
From 20 to 12 inches...	Time in seconds	291·5	244	245
	Time of oxygen=1...	0·8997	0·7531	0·7561
From 12 to 8 inches ...	Time in seconds	205·5	170	170·5
	Time of oxygen=1...	0·9000	0·7456	0·7478
From 8 to 4 inches......	Time in seconds	334	276	276
	Time of oxygen=1...	0·8966	0·7410	0·7410
From 4 to 2 inches......	Time in seconds	343	284	287
	Time of oxygen=1...	0·8831	0·7310	0·7400
From 28 to 4 inches ...	Time in seconds	1064·5	888	890
	Time of oxygen=1...	0·8983	0·7493	0·7514

It will be observed that the numbers do not differ materially from those obtained with glass tubes, particularly with H. This is a capillary of great resistance, and therefore a deviation from uniformity of ratio may be looked for in the lower part of the scale. A little irregularity in the rate of air, probably accidental, appears in the upper part of the scale; but as with capillary H, the coefficient for air never varies far from 0·9, at least between 28 and 4 inches.

Carbonic acid and nitrous oxide exhibit the usual parallelism of rate; but in the upper part of the scale the excess of the coefficient above ·75 is rather considerable. Other experiments were made on the transpiration of carbonic acid into different aspirator jars, as the size of the jar and duration of the experiment appeared to have some influence on the ratios.

TABLE XXVI.—Transpiration by Copper Capillary into a one-pint jar. Barom. 29·07. Temp. 56°.

Gauge barometer in inches.	Oxygen.		Carburetted hydrogen.	
	I.	II.	I.	II.
	″	″	″	″
28	0	0	0	0
20	273	274	151	151
12	338	336	186	186
8	237	236	129	130
4	383	385	210	211
2	391	400	214	213
From 28 to 4 inches ...	1231	1231	676	678

Mean Results.

Gauge barometer.		Carburetted hydrogen.
From 28 to 20 inches	Time in seconds	151
	Time of oxygen=1...	0·5521
From 20 to 12 inches	Time in seconds	186
	Time of oxygen=1...	0·5519
From 12 to 8 inches	Time in seconds	129·5
	Time of oxygen=1...	0·5475
From 8 to 4 inches	Time in seconds	210·5
	Time of oxygen=1...	0·5482
From 4 to 2 inches	Time in seconds	213·5
	Time of oxygen=1...	0·5398
From 28 to 4 inches	Time in seconds	677
	Time of oxygen=1...	0·5500

The coefficient obtained for carburetted hydrogen in the preceding experiments never varies much from 0·55, which is the mean between 28 and 4 inches. The result is similar to that given by glass capillary H for the same gas.

Table XXVII.—Transpiration by Copper Capillary into a two-pint jar. Barom. 29·49. Temp. 56°·5.

Gauge barometer in inches.	Air.		Oxygen.		Nitrogen.		Carbonic oxide.		Air.	Hydrogen.	
	I.	II.	I.	II.	I.	II.	I.	II.	III.	I.	II.
	″	″	″	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0	0	0	0
20	421	419	467	466	405	407	405	404	419	206	205
12	515	514	572	574	501	500	496	498	516	255	254
8	360	363	402	404	351	351	348	348	361	179	179
From 28 to 8 inches...	1296	1296	1441	1444	1257	1258	1249	1250	1296	640	638

Mean Results.

Gauge barometer.		Air.	Nitrogen.	Carbonic oxide.	Hydrogen.
From 28 to 20 inches	Time in seconds	420	406	404·5	205·5
	Time of oxygen=1...	0·9003	0·8703	0·8670	0·4405
From 20 to 12 inches	Time in seconds	514·5	500·5	497	254·5
	Time of oxygen=1...	0·8979	0·8734	0·8673	0·4441
From 12 to 8 inches	Time in seconds	361·5	351	348	179
	Time of oxygen=1...	0·8970	0·8709	0·8635	0·4441
From 28 to 8 inches	Time in seconds	1296	1257·5	1249·5	639
	Time of oxygen=1...	0·8984	0·8717	0·8662	0·4429

The great resemblance which these results bear to those of the last glass capillary is most surprising. The rates of air, nitrogen, carbonic oxide and hydrogen, may be considered as identical with these two capillaries, although they differ in substance, and also in the time of passage, which is slower in the copper capillary than in H, in the proportion of 22·12 to 15·64. Carbonic oxide, it will be observed, is still sensibly more rapid in its passage than nitrogen.

The experiments in the preceding and all other tables are put down in the order in which they were made. The observation with air is occasionally repeated, to find whether the rate of the capillary remains constant.

Table XXVIII.—Transpiration by Copper Capillary into a three-pint jar.
Barom. 29·73. Temp. 57°.

Gauge barometer in inches.	Air.		Oxygen.		Nitrogen.		Hydrogen.		Carbonic acid.	
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
	″	″	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0	0	0
20	595	595	663	660	575	577	287	287	500	502
12	736	735	818	819	713	713	358	357	616	613
8	516	517	575	577	500	501	251	252	426	428
From 28 to 8 inches...	1847	1847	2056	2056	1788	1791	896	896	1542	1543

Mean Results.

Gauge barometer.		Air.	Nitrogen.	Hydrogen.	Carbonic acid.
From 28 to 20 inches	Time in seconds	595	576	287	501
	Time of oxygen=1...	0·8994	0·8707	0·4339	0·7573
From 20 to 12 inches	Time in seconds	735·5	713	357·5	614·5
	Time of oxygen=1...	0·8986	0·8711	0·4369	0·7507
From 12 to 8 inches	Time in seconds	516·5	500·5	251·5	427
	Time of oxygen=1...	0·8967	0·8689	0·4366	0·7413
From 28 to 8 inches	Time in seconds	1847	1789·5	896	1542·5
	Time of oxygen=1...	0·8984	0·8704	0·4358	0·7502

The preceding results with air and nitrogen might be confounded with those obtained with capillary H. The rate of hydrogen is sensibly faster, while that of carbonic acid is decidedly slower; both gases diverging sensibly from their empirical rates 0·375 and 0·75, on the side of effusion, but the former very slightly.

Table XXIX.—Transpiration by Copper Capillary into a six-pint jar.
Barom. 30·14. Temp. 58°.

Gauge barometer in inches.	Air.		Oxygen.		Hydrogen.	
	I.	II.	I.	II.	I.	II.
	″	″	″	″	″	″
28	0	0	0	0	0	0
24	......	......	......	614	269	271
20	1139	1139	1268	654	290	290
12	1413	1413	1570	1573	698	699
8	994	993	1109	1110	494	495
From 28 to 8 inches.	3546	3545	3947	3951	1751	1755

Mean Results.

Gauge barometer.		Air.	Hydrogen.
From 28 to 20 inches	Time in seconds	1139	560
	Time of oxygen =1	0·8982	0·4416
From 20 to 12 inches	Time in seconds	1413	698·5
	Time of oxygen =1	0·8991	0·4445
From 12 to 8 inches	Time in seconds	993·5	494·5
	Time of oxygen =1	0·8955	0·4457
From 28 to 8 inches	Time in seconds	3545·5	1753
	Time of oxygen =1	0·8978	0·4439

In these experiments with a large aspirator jar and long times, the rate of air continues very nearly 0·9, and that of hydrogen approaches 0·44. The rates at the upper part of the scale are to be particularly attended to, as most uniform, and as representing pretty nearly transpiration into a vacuum.

TABLE XXX.—Transpiration by Copper Capillary into a six-pint jar.

Barom. 30·23. Temp. 58°·5.

Gauge barometer in inches.	Air.		Oxygen.		Carbonic acid.	
	I.	II.	I.	II.	I.	II.
	59°	59°	59°·25	59°	59°·5	59°·75
28	0″	0″	0″	0″	0″	0″
24	550	550	611	612	469	468
20	590	589	655	655	498	499
12	....	....	1570	1570	1183	1183
8	....	....	1103	1104	824	825
From 28 to 8 inches ...	....	....	3939	3941	2974	2975

Mean Results.

Gauge barometer.		Air.	Carbonic acid.
From 28 to 24 inches...	Time in seconds	550	468·5
	Time of oxygen=1...	0·8994	0·7661
From 24 to 20 inches...	Time in seconds	589·5	498·5
	Time of oxygen=1...	0·9000	0·7610
From 20 to 12 inches...	Time in seconds	....	1183
	Time of oxygen=1...	....	0·7535
From 12 to 8 inches ...	Time in seconds	....	824·5
	Time of oxygen=1...	....	0·7472
From 28 to 8 inches ...	Time in seconds	....	2974·5
	Time of oxygen=1...	....	0·7549

The preceding table contains an experiment on carbonic acid transpired into a large jar. The coefficient of that gas still considerably exceeds 0·75 in the upper part of the scale.

It appears then that the rates of transpiration are similar through glass and copper tubes, for air, oxygen, nitrogen, hydrogen and carburetted hydrogen; whilst the passage of carbonic acid is subject to a retardation in the upper part of the scale of the copper capillary, by which its rate increases so much as from 0·75 to 0·7661, in the last series of experiments. The rate of carbonic acid indeed exhibits a want of steadiness with this capillary, which is not observed in the other gases enumerated. Thus we find it in the upper part of the scale 0·7639 by Table XXV.; 0·7573 by Table XXVIII.; and 0·7661 by the last table. I may add, that in a preliminary experiment which was made with this gas, and also in an experiment made subsequently to those recorded, and after the tube had been some weeks out of use, so high a coefficient was given for carbonic acid as 0·78. It is impossible to say whether this irregularity is properly referable to the material of the tube, or is peculiar to this individual capillary, as it is the only instrument of the same metal which was used.

The copper tube has no advantage over the glass capillary for experiments on transpiration, while it is liable to the objection that it cannot be used at all with certain gases which have a chemical action on copper, and would tarnish the surface of the tube. The experiments made with it, however, have their value in demonstrating that the rates of transpiration of different gases are essential properties of these gases, and not regulated by the material of the transpiring tube. Indeed there is no more reason to suppose that the coefficient of transpiration of a gas would vary with the substance of the tube, than that the specific gravity of the same gas would be found different according as it was observed in a glass or copper vessel.

6. *Transpiration of different Gases by a Glass Capillary Tube* E.

This was another long capillary glass tube, resembling H, but somewhat shorter. The extreme length of capillary E was 20 feet; it allowed 1 cubic inch of air to pass into a vacuum in 12·03 seconds. One inch of this tube at either end was found to contain 1 grain and 0·94 grain of mercury; the smallest of which admeasurements gives 0·0187 inch as the diameter of the tube; that is, about $\frac{1}{53\cdot5}$th of an inch.

The following table contains a series of experiments on various gases, which were made on one occasion, and in the order in which they are given.

Table XXXI.—Transpiration by Capillary E into a six-pint jar.
Barom. 30·340—30·288.

ge barometer n inches.	Air.		Oxygen.		Carburetted hydrogen.		Hydrogen.		Carbonic oxide.		Nitrogen.		Nitrous oxide.		Carbonic acid.		A
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.
	72°	72°	72°	72°·25	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75	72°·75
28·5	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
26·5	153	153	172	170	93	93	75	74	150	149	150	149	129	129	130	130	154
24·5	156	156	173	175	97	97	75	76	150	151	151	153	133	133	132	132	158
23·5	84	84	92	92	52	50	41	40	80	80	81	80	70	70	70	70	84
8·5 to 23·5 in.	393	393	437	437	242	240	191	190	380	380	382	382	332	332	332	332	396

Mean Results.

Gauge barometer.		Air.	Carburetted hydrogen.	Hydrogen.	Carbonic oxide.	Nitrogen.	Nitrous oxide.	Carbonic acid.	Air.
From 28·5 to 23·5 in.	Time in seconds	393	241	190·5	380	382	332	332	396
	Time of ox. =1	0·8993	0·5515	0·4359	0·8696	0·8741	0·7597	0·7597	0·9062

This table exhibits the transpiration of the gases by E, in the upper part of the scale or into a vacuum nearly, the condition in which the subject is studied with most advantage. The coefficients exhibit a close correspondence with those found by the two preceding capillaries. The number for air is 0·8993 at the beginning, and 0·9062 at the end of the experiments; a variation of rate to which this capillary appeared more liable than the others. The number for nitrogen, 0·8741, again slightly exceeds that for carbonic oxide, 0·8696. Nitrous oxide and carbonic acid have the same number 0·7597, which is in excess compared with 0·75; while the number for hydrogen, 0·4359, is slightly deficient compared with 0·4375. Carburetted hydrogen has the number 0·5515, and is wonderfully constant with all these long capillaries.

As the time of transpiration in these experiments appeared rather short for exact results, a larger aspirator-jar was employed, and the experiment repeated with carbonic acid; air and oxygen being added to give standards of comparison.

Table XXXII.—Transpiration by Capillary E into a nine-pint jar. Barom. 30·136. Temp. 74°·5.

Gauge barometer in inches.	Air.		Oxygen.		Carbonic acid.	
	I.	II.	I.	II.	I.	II.
28·5	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0
26·5	229	229	254	254	190	191
24·5	233	232	259	258	195	195
23·5	121	121	135	135	104	103
From 28·5 to 23·5......	583	582	648	647	489	489

Mean Results.

Gauge barometer.		Air.	Carbonic acid.
From 28·5 to 23·5 inches	Time in seconds	582·5	489
	Time of oxygen=1...	0·8996	0·7550

As the result for carbonic acid differed sensibly from the experiment of the preceding table, it was considered desirable to return to the subject on the following day. In the meantime the barometer had fallen considerably, which accounts for the comparative slowness of transpiration in the following repetition of the last experiments.

Repetition of the last experiments. Barom. 29·616—29·666. Temp. 72°.

Gauge barometer in inches.	Air.		Oxygen.		Carbonic acid.	
	I.	II.	I.	II.	I.	II.
28·5	0″	0″	0″	0″	0″	0″
26·5	237	236	262	262	196	197
24·5	239	239	266	266	199	202
23·5	129	129	141	141	107	106
From 28·5 to 23·5 inches	605	604	669	669	502	505

Mean Results.

Gauge barometer.		Air.	Carbonic acid.
From 28·5 to 23·5 inches	Time in seconds	604·5	503·5
	Time of oxygen =1...	0·9036	0·7526

The three results for carbonic acid by this capillary are therefore 0·7597, 0·7550 and 0·7526; of which the mean is 0·7558. The coefficient of capillary E for carbonic acid is therefore not so widely different from 0·75 as it at first appeared.

With these large aspirator jars the rise of temperature within the jar during the experiment becomes very small. In the six-pint jar it did not amount to one-quarter of a degree Fahr., and in the nine-pint jar it was altogether insensible.

I have now detailed the results of the transpiration of gases by all the capillaries used except one,—a tube with which a few preliminary experiments in the inquiry were made, not sufficiently precise to merit being recorded. All of these tubes have given the same coefficient of transpiration to each gas, or coefficients closely approximating, although the tubes themselves have varied considerably in their respective dimensions; namely, in diameter, from $\frac{1}{45}$th to $\frac{1}{186}$th of an inch; in length from 2 inches to 22 feet; and from 12 to 70 seconds in the time of transmission of one cubic inch of air into a vacuum. It can be said that no selection of the tubes was made; and their dimensions are in a great measure accidental.

From the agreement in results obtained with tubes so different in dimensions, I consider that a glass tube of any diameter whatever will be found suitable for observations on transpiration, provided a certain length is given to it. If the tube is extremely short, a mere ring, then we know that gases will be transmitted by it into a vacuum according to the law of effusion; oxygen, hydrogen and carbonic acid in times expressed by 1, 0·25 and 1·176 respectively. With the slightest elongation of the tube these ratios are disturbed; the number for hydrogen soon increasing to 0·35 or 0·40, and that for carbonic acid falling to 1, or 0·80, referring both to the time of oxygen always taken as unity. The change with the increase of length is very great at first, but soon falls off, and with a certain length of tube seems to cease altogether. The coefficient of hydrogen is then found to have risen to some number approaching closely to 0·4375 or 0·44, and the coefficient of carbonic acid to approach closely to 0·75. The coefficient of nitrogen has fallen at the same time from 0·9373 (its coefficient of effusion, that of oxygen being 1) to nearly 0·875.

With this length of the tube, the influence of effusion upon the transpiration rate of the gas has ceased to be sensible.

The action of the tube attains a certain uniformity, at the same time, in another respect. When the tube is deficient in length, the coefficient of the gas varies greatly with the extent of the exhaustion of the vessel into which the gas is flowing; the rate of transpiration inclining most to the rate of effusion at a high degree of exhaustion of the aspirator jar. But the amount of this variation progressively diminishes as the tube becomes longer, till at last the coefficient of transpiration remains nearly if not perfectly constant, whether the aspirator jar be entirely vacuous, or contains already gas of the tension of half an atmosphere, three-fourths or even seven-eighths of an atmosphere.

The tube is now of the length most favourable for experiments of transpiration. Farther addition to the tube appears to have no effect in altering the coefficient of transpiration of air, provided the aspirator jar into which the air passes is vacuous or nearly so; or the coefficient of transpiration into a vacuum appears to remain constant for all greater lengths of the tube. But the extent of the barometric range in the aspirator jar to which the vacuum coefficient is found to apply is gradually limited. Instead of extending over seven-eighths of an atmosphere it may be contracted to an eighth of an atmosphere or less, by greatly lengthening the tube.

The coefficients of transpiration which I have endeavoured to ascertain are properly therefore the relative times of passage of the gases into a vacuum, at the mean atmospheric temperature, or near that temperature.

But even with the most favourable length of the tube, when the aspiration is feeble, and does not exceed 2 or 3 inches of mercury, the rate of transpiration is modified from an interference, which is connected with the excessive resistance of the tube to the passage of the gas. I have not been able to undertake an examination of the nature and extent of this interference, but suppose it to depend upon friction, while the rate of transpiration seems again to depend upon a constitutional difference in the gases themselves.

The theory of the transpirability of gases, which at present appears to me most probable, is that it is a kind of elasticity depending upon the absolute quantity of heat, latent as well as sensible, which different gases contain under the same volume; and therefore that it will be connected more immediately with the specific heat than any other property of the gases.

The only other gases besides those already experimented upon, which could be retained over water, and exposed to the metallic parts of the apparatus without injury, are olefiant gas, nitric oxide and sulphuretted hydrogen; and these were submitted to transpiration with several of the tubes already used. I subjoin the results, although less complete than is desirable, under the head of each gas.

7. *Transpiration of Olefiant Gas.*

TABLE XXXIII.—Transpiration by Capillary H into a six-pint jar. Barom. 29·68. Temp. 59°.

Gauge barometer in inches.	Air.		Olefiant gas.	
	I.	II.	I.	II.
	″	″	″	″
28·5	0	0	0	0
26·5	217	218	124	128
24·5	220	220	130	131
23·5	112	113	66	65
From 28·5 to 23·5 inches ...	549	551	320	324

Transpiration by Capillary H into a one-pint jar.

Gauge barometer in inches.	Air.		Olefiant gas.		Air.
	I.	II.	I.	II.	I.
	″	″	″	″	″
28	0	0	0	0	0
20	184	183	108	108	183
12	227	228	134	134	226
8	163	163	96	96	163
4	265	265	153	151	265
2	260	264	149	149	260
From 28 to 2 inches	1099	1103	640	638	1097

		Air.	Olefiant gas.
From 28·5 to 23·5 inches	Time in seconds	550	322
	Time of air=1	....	0·5854
	Time of oxygen=1....	....	0·5268

		Air.	Olefiant gas.
From 28 to 2 inches......	Time in seconds	1099·7	639
	Time of air=1	....	0·5810
	Time of oxygen=1 ...	....	0·5229

TABLE XXXIV.—Transpiration by Capillary H (with cupped ends) into a six-pint jar. Barom. 30·2. Temp. 52°.

Gauge barometer in inches.	Air.		Carburetted hydrogen.		Olefiant gas.		Air.	$90C_4H_4+10CO$.		Air.	
	I.	II.	I.	II.	I.	II.	I.	I.	II.	I.	II.
	″	″	″	″	″	″	″	″	″	″	″
28·5	0	0	0	0	0	0	0	0	0	0	0
26·5	206	207	127	126	120	118	207	126	126	207	207
24·5	208	208	127	128	119	121	208	126	127	209	209
23·5	106	106	64	65	61	61	106	64	64	104	104
From 28·5 to 23·5 inches ...	520	521	318	319	300	300	521	316	317	520	520

Mean Results.

Gauge barometer.		Air.	Carburetted hydrogen.	Olefiant gas.	$90C_4H_4+10CO$.	Air.
From 28·5 to 23·5 inches	Time in seconds	521·5	318·	300	316·5	
	Time of air=1	....	0·6118	0·5763	0·6080	
	Time of oxygen=1....	....	0·5506	0·5186	0·5472	

The results for olefiant gas can be considered only as approximative from the circumstance that the gas was always contaminated by a small quantity of carbonic oxide, varying from 3 to 5 per cent., and a sensible trace of the dense gas or vapour, to which allusion has already been made. Both impurities would tend to raise the number for olefiant gas; ten per cent. of carbonic oxide purposely added to that gas, raising its number from 0·5186 to 0·5472. The calculated mean rate of the last mixture is 0·5513, taking the rate of carbonic oxide at 0·8700, and that of olefiant gas at 0·5186. If the true coefficient for olefiant gas should be a whole number, it may be expected to be 0·5, or exactly one-half of the rate of oxygen.

8. *Transpiration of Nitric Oxide.*

TABLE XXXV.—Transpiration by Capillary E into a one-pint jar. Barom. 30·45. Temp. 52°.

Gauge barometer in inches.	Air.	Nitric oxide.		Oxygen.	Air.
	I.	I.	II.	I.	I.
	″	″	″	″	″
28	0	0	0	0	0
20	135	135	131	149	135
12	167	162	162	186	169
8	118	115	115	133	118
4	189	183	184	206	188
2	192	184	188	219	195
From 28 to 4 inches ...	609	595	592	674	610

Mean Results.

Gauge barometer.		Air.	Nitric oxide.	Air.
From 28 to 4 inches......	Time in seconds	609	593·5	610
	Time of oxygen=1....	0·9035	0·8805	0·9035

TABLE XXXVI.—Transpiration by Capillary E into a two-pint jar. Barom. 30·08. Temp. 60°.

Gauge barometer in inches.	Nitrogen.			Nitric oxide.		Oxygen.	
	I.	II.	III.	I.	II.	I.	II.
	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0
20	231	232	......	237	235	266	267
12	286	287	286	288	287	327	328
8	200	200	202	203	206	227	227
4	320	317	320	313	312	363	364
2	314	320	316	311	315	361	361
From 28 to 2 inches...	1351	1356	......	1352	1355	1544	1547

Mean Results.

Gauge barometer.		Nitrogen.	Nitric oxide.
From 28 to 12 inches	Time in seconds	517·83	523·5
	Time of oxygen=1...	0·8717	0·8815
From 12 to 4 inches	Time in seconds	519·7	517
	Time of oxygen=1...	0·8801	0·8755
From 4 to 2 inches	Time in seconds	316·7	313
	Time of oxygen=1...	0·8772	0·8670
From 28 to 2 inches	Time in seconds	1354·2	1353·5
	Time of oxygen=1...	0·8768	0·8764

The number for nitric oxide (NO_2) approaches very closely to that of nitrogen, if it does not actually coincide with that number; yet the specific gravities of these two gases are different, that of nitric oxide being 1·0405, air =1 ; or 0·9375, oxygen =1 ; the mean between the densities of oxygen and nitrogen gases. It would appear from this that the coefficients of transpiration of gases are less various than their specific gravities. In conducting experiments with this gas, the surface of the mercury in the gauge tube is tarnished, which causes it to adhere to the glass and descend irregularly, so that the observations want the usual uniformity, as seen in both tables. When a few drops of water were placed above the mercury in the gauge barometer, its descent became more regular. This gas acted inconveniently in another way, by forming a solid compound with the oil in the cylinders, and thus clogging the action of the air-pump.

9. *Transpiration of Sulphuretted Hydrogen.*

TABLE XXXVII.—Transpiration by Capillary H into a one-pint jar. Barom. 29·89. Temp. 59°.

Gauge barometer in inches.	Air.		Sulphuretted hydrogen.			Air.
	I.	II.	I.	II.	III.	I.
	″	″	″	″	″	″
28	0	0	0	0	0	0
20	180	180	122	123	121	178
12	226	224	156	153	153	225
8	155	158	108	109	110	156
4	262	257	177	174	173	258
2	253	256	175	173	173	255
From 28 to 2 inches...	1076	1075	738	732	730	1072

Mean Results.

Gauge barometer.		Sulphuretted hydrogen.
From 28 to 12 inches	Time in seconds	276
	Time of air... =1...	0·6814
	Time of oxygen=1...	0·6132
From 12 to 4 inches	Time in seconds	283·66
	Time of air... =1...	0·6738
	Time of oxygen=1...	0·6060
From 4 to 2 inches	Time in seconds	173·66
	Time of air... =1...	0·6825
	Time of oxygen=1...	0·6142
From 28 to 2 inches	Time in seconds	733·3
	Time of air... =1...	0·6818
	Time of oxygen=1...	0·6136

TABLE XXXVIII.—Transpiration by Capillary H into a six-pint jar. Barom. 29·98. Temp. 59°.

Gauge barometer in inches.	Air.		Sulphuretted hydrogen.				Air.			
	I.	II.	I.	II.	III.	IV.	I.	II.	III.	IV.
	″	″	″	″	″	″	″	″	″	″
28·5	0	0	0	0	0	0	0	0	0	0
26·5	206	203	140	140	140	141	206	203	203	205
24·5	207	209	143	147	146	148	216	214	217	215
23·5	107	109	77	75	77	75	108	109	109	111
From 28·5 to 23·5 inches	520	521	360	362	363	364	530	526	529	531

Mean Results.

Gauge barometer.		Sulphuretted hydrogen.
From 28·5 to 23·5 inches	Time in seconds	362·25
	Time of air... =1...	0·6846
	Time of oxygen=1...	0·6161

The experiments with this gas indicate a number above 0·60 for its coefficient of transpiration; 0·625 is 5-8ths of oxygen, while the result of Table XXXVIII., which is the more valuable of the two, is 0·6161. But this gas is likely to vary sensibly in its coefficient with different capillaries, like carbonic acid; and both its physical and chemical properties oppose difficulties to obtaining a correct result. The rate of air following this gas is made very sensibly slower in the last table; indeed the rate of the capillary appears to be permanently altered, possibly from the deposition of sulphur from the gas.

[I shall add, in an Appendix to this paper, a series of observations on the transpiration of gaseous mixtures, which appear to warrant the following conclusions:—

It appears from Tables XLII. and XLIII., that mixtures of oxygen and nitrogen in all proportions maintain a rate which is sensibly the arithmetical mean rate of the two gases.

From Tables XLIV. and XLV., that the rates of mixtures of oxygen and carbonic oxide are also uniform, but that mixtures of carbonic oxide and hydrogen deviate greatly from the mean, inclining always to that of the heavier gas.

In Tables XLVI. and XLVII., that the mixtures of oxygen and carbonic acid maintain the mean rate; and that mixtures of carburetted hydrogen and hydrogen deviate greatly from the mean, always inclining to the rate of the slower gas.

Tables from XLVIII. to LIII. inclusive, exhibit the transpiration of hydrogen mixed with various other gases, particularly nitrogen, oxygen, carbonic acid, nitrous oxide, and nitric oxide; and Tables LIV. and LV. contain the results of the transpiration of mixtures of carburetted hydrogen with oxygen and with hydrogen. It appears that while all the other gases tried appeared to maintain their usual rates of transpiration in a state of mixture, those of carburetted hydrogen and hydrogen are greatly altered; and when the proportion of the latter gas is not more than from 5 to 15 per cent., its rate becomes as slow as the densest gas with which it is mixed; the deviation from the mean in hydrogen mixtures being relatively greatest when one of the gases is present in a small proportion. With an addition of so much as 25 per cent. of hydrogen, carburetted hydrogen, carbonic acid and nitrous oxide continue to be transpired in sensibly the same times as when pure and unmixed. Hydrogen is then transpired of course as slowly as the other gas with which it is mixed, although the time of hydrogen alone is 0·44, while that of carburetted hydrogen is 0·55, and of carbonic acid and nitrous oxide 0·75. Indeed small additions of hydrogen, such as 5 or 10 per cent., made to carburetted hydrogen, appear to prolong the time of transpiration; and what is very curious, raise the time of the mixture to the empirical number of pure carburetted hydrogen, namely, 0·5625 (Table XLVII.). A slight retardation of the same kind may also be perceived in the similar carbonic acid mixtures. The transpiration-time of equal volumes of hydrogen and carbonic acid is 0·7339, or very little less than that of pure carbonic acid.

Carbonic oxide and nitric oxide, with equal admixtures of hydrogen, correspond as closely in their times as when pure, as will be seen on comparing together the results of Tables XLV. and LIII. A similar apparent rectification of the time of nitric oxide will be observed, in the last of these tables, to be effected by the addition of 5 per cent. of hydrogen to that gas, as was remarked above of carburetted hydrogen; the time of 100 NO_2 being 0·8661, that of 95 NO_2+5H is found 0·8788; while the empirical coefficient for nitric oxide is the same as that of nitrogen, namely, 0·8750, or 0·8785, adopting Regnault's density of the latter gas.

It appears that the time of carburetted hydrogen is sensibly increased by the addition of oxygen, at least when the proportion of the latter gas amounts to or exceeds 25 per cent. of the mixture (Table LIV.).

The times of transpiration of the hydrogen mixtures, which have been most minutely observed, namely, those of hydrogen with oxygen, with air, and with carbonic acid, are exhibited by the curves of Plate XXXV. These curves start from a common point 44, the time of pure hydrogen, and terminate respectively with the times of oxygen 100, of air 90, and of carbonic acid 75.

It would be premature to enter at present upon any discussion of these results; for the full elucidation of the transpiration of mixed gases, must await, I believe, the further extension of our knowledge of the laws of gaseous diffusion. Nov. 1846.]

APPENDIX.

Tables of the observed Transpiration of Gaseous Mixtures.

TABLE XLII.—Transpiration by Capillary E into a one-pint jar. Barom. 29·55. Temp. 53°.

Gauge barometer in inches.	Air.		Oxygen.		97·5O+2·5N.		95O+5N.		90O+10N.		75O+25N.		66·6O+33·3N.		Oxygen.
	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.
28	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	142	143	158	158	......	......	157	158	156	157	153	153	151	151	157
12	176	175	196	195	353	353	194	194	192	192	190	189	187	187	195
8	123	123	137	138	137	137	137	136	136	136	133	134	131	132	137
4	197	197	222	220	220	219	220	219	218	216	214	214	211	211	220
2	199	197	221	222	222	223	220	221	219	221	218	219	212	212	222
From 28 to 2 inches.	837	835	934	933	932	932	928	928	921	922	908	909	892	893	931

Mean Results.

Gauge barometer.		Air.	97·5O+2·5N.	95O+5N.	90O+10N.	75O+25N.	66·6O+33·3N.	Oxygen.
From 28 to 2 inches.	Time in seconds	836	932	928	921·5	908·5	892·5	
	Time of oxygen = 1...	0·8955	0·9984	0·9941	0·9871	0·9734	0·9550	
	Calculated mean	....	0·9969	0·9938	0·9875	0·9688	0·9583	

TABLE XLIII.—Transpiration by Capillary E into a one-pint jar. Barom. 29·81. Temp. 54°.

Gauge barometer in inches.	Air.		50N+50O.		Oxygen.	66·6N+33·3O.	75N+25O.	90N+10O.	95N+5O.	97·5N+2·5O.	Nitrogen.	Air.
	I.	II.	I.	II.	I.	I.	I.	I.	I.	I.	I.	I.
28	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	140	141	147	147	157	143	142	139	139	139	138	145
12	174	173	181	181	193	177	176	172	170	170	169	175
8	122	123	128	128	137	125	123	121	120	120	119	124
4	196	196	204	204	219	199	198	193	192	193	192	198
2	197	196	208	207	222	204	201	196	196	199	194	198
From 28 to 2 inches.	829	829	868	867	928	848	840	821	817	821	812	840

Mean Results.

Gauge barometer.		Air.	50N+50O.	66·6N+33·3O.	75N+25O.	90N+10O.	95N+5O.	97·5N+2·5O.	Nitrogen.	Air.
From 28 to 2 inches	Time in seconds ...	829	867·5	848	840	821	817	821	812	840
	Time of oxygen = 1	0·8933	0·9348	0·9138	0·9051	0·8847	0·8804	0·8847	0·8750	0·9052
	Calculated mean ...	....	0·9375	0·9167	0·9062	0·8875	0·8812	0·8805	0·8789	

TABLE XLIV.—Transpiration by Capillary E into a one-pint jar. Barom. 29·69. Temp. 54°.

Gauge barometer in inches.	Oxygen.	Carbonic oxide.	97·5CO+2·5O.	95CO+5O	90CO+10O.	75CO+25O.	Air.	Oxygen.
	I.	I.	I.	I.	I.	I.	I.	I.
28	0″	0″	0″	0″	0″	0″	0″	0″
20	157	137	139	138	140	142	143	158
12	195	169	169	170	172	176	175	196
8	137	118	120	120	120	124	123	138
4	219	192	191	192	194	198	197	221
2	221	190	192	193	202	202	199	221
From 28 to 4 inches ...	708	616	619	620	626	640	638	713

Mean Results.

Gauge barometer.		Carbonic oxide.	97·5CO+2·5O.	95CO+5O.	90CO+10O.	75CO+25O.	Air.	Oxygen.
From 28 to 4 inches...	Time in seconds ...	616	619	620	626	640	638	
	Time of oxygen=1.	0·8701	0·8743	0·8757	0·8842	0·9040	0·9011	
	Calc. mean	....	0·8733	0·8765	0·8830	0·9026		

TABLE XLV.—Transpiration by Capillary E into a one-pint jar. Barom. 30·18. Temp. 52°.

Gauge barometer in inches.	Air.	Carbonic oxide.	66·7CO+33·3O.	50CO+50O.	66·7O+33·3CO.	75O+25CO.	Oxygen.	95CO+5H.	90CO+10H.	75CO+25H.	92·5CO+7·5H.	Air.	Hydrogen.
	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.
28	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	137	132	140	143	146	148	152	133	132	128	132	137	78
12	169	164	172	177	181	183	189	164	163	159	163	170	84
8	119	116	122	125	128	130	133	115	116	113	115	121	59
4	192	185	195	200	206	205	215	184	185	181	185	193	95
2	193	188	201	205	209	204	219	190	191	181	191	201	100
From 28 to 4 inches...	617	597	629	645	661	666	689	596	596	581	595	621	316

Mean Results.

Gauge barometer.		Air.	Carbonic oxide.	66·7CO+33·3O.	50CO+50O.	66·7O+33·3CO.	75O+25CO.	95CO+5H.	90CO+10H.	75CO+25H.	92·5CO+7·5H.	Air.	Hydrogen.
From 28 to 4 inches.	Time in sec....	617	597	629	645	661	666	596	596	581	595	621	316
	Time of ox.=1	0·8905	0·8664	0·9129	0·9361	0·9593	0·9666	0·8650	0·8650	0·8432	0·8635	0·9013	0·4586
	Calc. mean, A*.	....	....	0·9109	0·9332	0·9554	0·9666	0·8046	0·8256	0·7644	0·8358		
	Calc. mean, B†.	....	....	....	....	....	....	0·8450	0·8237	0·7848	0·8344		

* Mean with the number for hydrogen actually observed.

† Mean with the number 0·44 as the coefficient of hydrogen. These last results are most to be depended upon, as the rate of the hydrogen alone is often raised by a slight impurity, of which the effect would become much less sensible in the mixtures containing that gas.

TABLE XLVI.—Transpiration by Capillary E into a one-pint jar. Barom. 29·94. Temp. 56°.

Gauge barometer in inches.	Air.	Oxygen.	Carbonic acid.	$97·5CO_2+2·5O$.	$95CO_2+5O$.	$90CO_2+10O$.	$75CO_2+25O$.	$50CO_2+50O$.	Carbonic acid.
	I.	I.	I.	I.	I.	I.	I.	I.	I.
28	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0
20	139	155	118	119	…………	120	127	136	117
12	172	192	144	145	266	149	156	168	145
8	……	135	101	102	102	104	109	118	102
4	315	218	161	163	163	166	174	188	161
2	198	218	161	162	163	166	175	190	162
From 28 to 2 in.	824	918	685	691	694	705	741	800	687

Mean Results.

Gauge barometer.		Air.	Carbonic acid.	$97·5CO_2+2·5O$.	$95CO_2+5O$.	$90CO_2+10O$.	$75CO_2+25O$.	$50CO_2+50O$.	Carbonic acid.
From 28 to 2 inches	Time in seconds …	824	685	691	694	705	741	880	687
	Time of oxygen = 1	0·8976	0·7461	0·7538	0·7559	0·7679	0·8071	0·8714	0·7467
	Calculated mean…	…………	…………	0·7524	0·7588	0·7715	0·8096	0·8730	

TABLE XLVII.—Transpiration by Capillary E into a one-pint jar. Barom. 29·61. Temp. 54°.

auge baro-meter in inches.	Carburetted hydrogen.	$90CH_2+10H$.	$95CH_2+5H$.	$97·5CH_2+2·5H$.	Hydrogen.	Oxygen.	$90O+10CO_2$.	$75O+25CO_2$.	$95O+5CO_2$.	$97·5O+2·5CO_2$.	Carbonic acid.	$82·5CH_2+17·5H$
	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.
28	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0	″ 0
20	87	89	89	87	71	158	154	149	155	156	119	88
12	107	110	109	107	88	194	189	183	192	193	147	109
8	………	76	76	75	61	137	133	128	134	136	102	75
4	195	123	123	120	98	218	214	206	217	218	163	122
2	121	124	123	122	102	224	219	211	222	224	166	123
rom 28 to 4 in.	389	398	397	389	318	707	690	666	698	703	531	394

Mean Results.

Gauge barometer.		Carburetted hydrogen.	$90CH_2+10H$.	$95CH_2+5H$.	$97·5CH_2+2·5H$.	Hydrogen.	$90O+10CO_2$.	$75O+25CO_2$.	$95O+5CO_2$.	$97·5O+2·5CO_2$.	Carbonic acid.	$82·5CH_2+17·5H$.
From 28 to 4 in.	Time in seconds	389	398	397	389	318	690	666	698	703	531	394
	Time of ox. = 1	0·5544	0·5629	0·5615	0·5502	0·4497	0·9759	0·9420	0·9872	0·9943	0·7510	0·5572
	Calc. mean, A*	…………	0·5439	0·5266	0·5409	…………	0·9750	0·9375	0·9875	0·9937	…………	0·5360
	Calc. mean, B†	…………	0·5429	0·5486	0·5515	…………	…………	…………	…………	…………	…………	0·5343

* Mean with the number for hydrogen actually observed.

† Mean with the number 0·44 as the coefficient of hydrogen. These last results are most to be depended upon, as the rate of the hydrogen alone is often raised by a slight impurity, of which the effect would become much less sensible in the mixtures containing that gas.

Table XLVIII.—Transpiration by Capillary E into a one-pint jar. Barom. 29·63. Temp. 52°.

Gauge barometer in inches.	Air.		Air.	Oxygen.		97·5O+2·5H.		95O+5H.		90O+10H.		75O+25H.		Hydrogen.	
	I.	II.	I.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.	I.	II.
28	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	141	142	142	158	158	157	157	157	157	156	156	153	153	70	70
12	177	176	176	195	195	194	195	195	194	194	194	189	189	87	87
8	122	122	122	137	136	137	136	136	137	135	136	133	132	62	62
4	197	196	196	219	219	218	219	218	219	217	217	213	213	99	99
2	195	196	199	219	221	219	217	223	221	221	221	216	215	100	100
From 28 to 2 inches	832	832	835	928	929	925	924	929	928	923	924	904	902	418	418

Mean Results.

Gauge barometer.		Air.	97·5O+2·5H.	95O+5H.	90O+10H.	75O+25H.	Hydrogen.
From 28 to 2 inches	Time in seconds	833	924·5	928·5	923·5	903	418
	Time of oxygen = 1...	0·8971	0·9957	1·000	0·9946	0·9724	0·4502
	Calculated mean A....	....	0·9862	0·9725	0·9450	0·8625	
	Calculated mean B....	....	0·9860	0·9720	0·9440	0·8600	

Table XLIX.—Transpiration by Capillary E into a one-pint jar. Barom. 29·57. Temp. 55°.

Gauge barometer in inches.	Air.	Hydrogen.	50H+50N.	25H+75CO_2.	10H+90CO_2.	25H+75CH_2.	Carburetted hydrogen.	Oxygen.	Nitrogen.	Air.
	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.
28	0″	0″	0″	0″	0″	0″	0″	0″	0″	0″
20	143	71	127	120	120	90	88	158	138	142
12	175	87	156	146	147	109	108	195	170	176
8	......	62	105	103	103	76	75	136	120	122
4	321	99	181	166	164	122	121	221	189	199
2	194	99	173	159	158	122	118	213	191	196
From 28 to 4 inches	639	319	569	535	534	397	392	710	617	639

Mean Results.

Gauge barometer.		Air.	Hydrogen.	50H+50N.	25H+75CO_2.	10H+90CO_2.	25H+75CH_2.	Carburetted hydrogen.	Nitrogen.	Air.
From 28 to 4 inches	Time in seconds ...	639	319	569	535	534	397	392	617	639
	Time of oxygen = 1	0·9000	0·4493	0·8014	0·7535	0·7521	0·5591	0·5521	0·8690	0·9000
	Calculated mean A.	....	....	0·6590	0·6723	0·7172	0·5264			
	Calculated mean B.	....	....	0·6545	0·6702	0·7163	0·5240			

TABLE L.—Transpiration by Copper Capillary into a three-pint jar. Barom. 30·1. Temp. 61°.

Gauge barometer in inches.	Air.		Hydrogen.		95H+5 Air.		90H+10 Air.	75 H+25 Air.	H25+75 Air.
	I.	II.	I.	II.	I.	II.	I.	I.	I.
	61°·25	61°·25	61°·5	61°·5	61°·75	61°·75	61°·75	61°·75	61°·75
28	0″	0″	0″	0″	0″	0″	0″	0″	0″
24	286	285	139	140	168	165	183	227	280
20	301	302	148	148	178	177	196	241	296
12	729	731	358	360	431	424	474	581	705
8	515	512	254	257	306	300	343	412	507
	61°·75	61°·75	62°	62°	62°	62°	62°	62°	62°
From 28 to 8 inches	1831	1830	899	905	1083	1066	1196	1461	1788

Transpiration by Copper Capillary into a three-pint jar. Barom. 30·19. Temp. 61°·5.

Gauge barometer in inches.	Air.		50H+50 Air.	10H+90 Air.	5H+95 Air.
	I.	II.	I.	I.	I.
	61°·5	61°·5	61°·5	61°·5	61°·5
28	0″	0″	0″	0″	0″
24	284	284	258	280	282
20	302	302	274	298	300
12	727	728	662	721	724
8	514	515	471	510	514
	62°	62°	62°	62°	62°
From 28 to 8 inches	1827	1829	1665	1809	1820

Mean Results.

Gauge barometer.		Air.	Hydrogen.	95H+5 Air.	90H+10 Air.	75H+25 Air.	25H+75 Air.
From 28 to 8 in.	Time in seconds ...	1803·5	902	1074·5	1196	1461	1788
	Time of air =1 ...	....	0·4927	0·5869	0·6534	0·7987	0·9767
	Time of oxygen=1	....	0·4434	0·5282	0·5880	0·7488	0·8790
	Calculated mean ...	....	....	0·4630	0·4860	0·5500	0·7850

		Air.	50H+50 Air.	10H+90 Air.	5H+95 Air.
From 28 to 8 in.	Time in seconds ...	1828	1665	1809	1820
	Time of air =1 ...	....	0·9108	0·9876	0·9956
	Time of oxygen=1	....	0·8197	0·8888	0·8960
	Calculated mean ...	....	0·6700	0·8540	0·8770

TABLE LI.—Transpiration by Capillary E into a one-pint jar. Barom. 29·89. Temp. 54°.

Gauge barometer in inches.	$97·5H+2·5CO_2$.	$95H+5CO_2$.	$90H+10CO_2$.	$75H+25CO_2$.	$50H+50CO_2$.	Carbonic acid.	Oxygen.	Hydrogen.	Air.
	I.	I.	I.	I.	I.	I.	I.	I.	I.
	″	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0	0
20	77	79	88	105	114	118	156	68	142
12	95	99	110	130	142	145	192	85	173
8	67	69	77	92	99	102	136	60	121
4	109	113	125	148	160	162	217	97	195
2	111	115	127	150	161	161	220	98	201
From 28 to 2 in.	459	475	527	625	676	688	921	398	832

Mean Results.

Gauge barometer.		$97·5H+2·5CO_2$.	$95H+5CO_2$.	$90H+10CO_2$.	$75H+25CO_2$.	$50H+50CO_2$.	Carbonic acid.	Hydrogen.	Air.
From 28 to 8 in.	Time in seconds	459	475	527	625	676	688	398	832
	Time of ox. =1	0·4983	0·5157	0·5722	0·6786	0·7339	0·7470	0·4321	0·9033
	Calculated mean	0·4402	0·4484	0·4648	0·5113	0·6455			

TABLE LII.—Transpiration by Capillary E into a one-pint jar. Barom. 30·39. Temp. 52°.

Gauge barometer in inches.	Air.	Oxygen.	Nitrous oxide.	75NO+25H.	90NO+10H.	Air.
	I.	I.	I.	I.	I.	I.
	″	″	″	″	″	″
28	0	0	0	0	0	0
20	136	152	114	114	114	135
12	168	187	141	141	141	168
8	119	132	99	99	98	119
4	189	212	157	159	158	190
2	198	222	159	162	159	196
From 28 to 4 inches...	612	683	511	513	511	612

Mean Results.

Gauge barometer.		Air.	Nitrous oxide.	75NO+25H.	90NO+10H.	Air.
From 28 to 4 inches	Time in seconds ...	612	511	513	511	612
	Time of oxygen=1	0·8960	0·7481	0·7510	0·7481	0·8960
	Calc. mean, A. ...	....	....	0·6757	0·7292	
	Calc. mean, B. ...					

TABLE LIII.—Transpiration by Capillary E into a one-pint jar. Barom. 30·62. Temp. 52°.

Gauge barometer in inches.	Air.	Oxygen.	Hydrogen.	Nitric oxide.		$95NO_2+5H$.
	I.	I.	I.	I.	II.	I.
	″	″	″	″	″	″
28	0	0	0	0	0	0
20	133	149	66	130	129	130
12	167	184	83	161	158	163
8	117	131	59	114	112	115
4	189	212	95	183	184	186
2	192	214	97	183	181	184
From 28 to 4 inches ...	606	676	303	588	583	594

Gauge barometer in inches.	$90NO_2+10H$.	$75NO_2+25H$.	$50NO_2+50H$.	$25NO_2+75H$.	Air.
	I.	I.	I.	I.	I.
	″	″	″	″	″
28	0	0	0	0	0
20	128	125	119	106	134
12	160	157	150	132	168
8	113	112	117	95	120
4	181	180	170	151	192
2	181	185	179	153	193
From 28 to 4 inches ...	582	574	556	484	614

Mean Results.

Gauge barometer.		Air.	Hydrogen.	Nitric oxide.	$95NO_2+5H$.
From 28 to 4 inches	Time in seconds	606	303	585·5	594
	Time of oxygen=1...	0·8964	0·4482	0·8661	0·8788
	Calc. mean, A.........	....	....	....	0·8452
	Calc. mean, B.........	....	....	....	0·8447
		$90NO_2+10H$.	$75NO_2+25H$.	$50NO_2+50H$.	$25NO_2+75H$.
From 28 to 4 inches	Time in seconds	582	574	556	484
	Time of oxygen=1...	0·8609	0·8491	0·8224	0·7159
	Calc. mean, A.........	0·8243	0·7616	0·6571	0·5527
	Calc. mean, B.........	0·8234	0·7596	0·6530	0·5465
		Air.			
From 28 to 4 inches	Time in seconds	614			
	Time of oxygen=1...	0·9082			

TABLE LIV.—Transpiration by Capillary E into a one-pint jar. Barom. 29·71. Temp. 55°.

Gauge barometer in inches.	Oxygen.	Carburetted hydrogen.	97·5CH$_2$+2·5O.	95CH$_2$+5O.	90CH$_2$+10O.	75CH$_2$+25O.	50CH$_2$+50O.	Air.
	I.	I.	I.	I.	I.	I.	I.	I.
	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0
20	157	91	91	92	94	109	127	141
12	195	109	112	114	117	134	157	174
8	136	77	79	79	81	94	110	122
4	219	122	126	127	131	151	177	195
2	224	124	127	129	133	153	180	200
From 28 to 4 inches	707	399	408	412	423	488	571	632

Mean Results.

Gauge barometer.		Carburetted hydrogen.	97·5CH$_2$+2·5O.	95CH$_2$+5O.	90CH$_2$+10O.	75CH$_2$+25O.	50CH$_2$+50O.	Air.
From 28 to 4 inches.	Time in seconds.	399	408	412	423	488	571	632
	Time of ox.=1...	0·5629	0·5770	0·5827	0·5983	0·6902	0·8076	0·8939
	Calc. mean.......	....	0·5734	0·5838	0·6062	0·6718	0·7814	

TABLE LV.—Transpiration by Capillary E into a one-pint jar. Barom. 29·43. Temp. 55°.

Gauge barometer in inches.	Air.	Hydrogen.	97·5H+2·5CH$_2$.	95H+5CH$_2$.	90H+10CH$_2$.	75H+25CH$_2$.	50H+50CH$_2$.	Carburetted hydrogen.	Hydrogen.	Oxygen.
	I.	I.	I.	I.	I.	I.	I.	I.	I.	I.
	″	″	″	″	″	″	″	″	″	″
28	0	0	0	0	0	0	0	0	0	0
20	144	73	75	77	79	84	88	88	74	160
12	176	91	93	94	98	105	109	108	92	197
8	124	64	65	66	68	73	76	76	65	138
4	198	103	105	107	111	119	122	121	105	222
2	201	105	107	109	113	120	126	123	106	225
From 28 to 4 inches ...	642	331	338	344	356	381	395	393	336	717

Mean Results.

Gauge barometer.		Air.	Hydrogen.	97·5H+2·5CH$_2$.	95H+5CH$_2$.	90H+10CH$_2$.	75H+25CH$_2$.	50H+50CH$_2$.	Carburetted hydrogen.	Hydrogen.
From 28 to 4 inches...	Time in sec....	642	331	338	344	356	381	395	393	336
	Time of ox.=1	0·8955	0·4616	0·4714	0·4797	0·4965	0·5313	0·5596	0·5481	0·4686
	Calc. mean, A	....	....	0·4705	0·4725	0·4765	0·4884	0·5083		
	Calc. mean, B.	....	....	0·4427	0·4454	0·4508	0·4670	0·4940		

XXIX. *On the Supra-renal, Thymus and Thyroid Bodies.*

By John Goodsir, *Esq. Communicated by* Richard Owen, *Esq., F.R.S., &c.*

Received June 19, 1845,—Read January 22, 1846.

While engaged, two years ago, in observing the structure of the lymphatic glands, my attention was directed to the thymus, thyroid, and supra-renal bodies; and I was led to frame a hypothesis, which, although afterwards requiring some modification, has, I conceive, nevertheless enabled me to detect, if not the real physiological, at least the morphological signification of these apparently anomalous organs.

My hypothesis was, that the thyroid, thymus and supra-renal bodies are the remains of the blastoderma; the thyroid being a portion of the original cellular substance of the germinal membrane grouped around the two principal branches of the omphalo-mesenteric vein; the supra-renal capsules, constituting other portions grouped around the omphalo-mesenteric arteries; and the thymus, the intermediate portion of the same membrane arranged along the sides of the embryonic visceral cavity.

Subsequent observations have satisfied me that this hypothesis is essentially correct, with the exception of that part of it relating to the thyroid, which body I have now ascertained to be a portion of the membrana intermedia of Reichert, which remains in connection with anastomosing vessels between the first and second aortic arches, or carotid and subclavian arteries.

In the embryo of the Sheep, while the branchial clefts are still open, and for some time afterwards, there is a quantity of blastema arranged in minute lobular masses around the anterior parts of the cardinal veins of Rathke, surrounding the jugular veins and ductus Cuvieri for a short distance behind the fore-part of the Wolffian bodies. Immediately in front of the Wolffian bodies these lateral masses of blastema are narrow, being scarcely perceptible on the coats of the cardinal veins; but around the ductus Cuvieri they are larger, and differ from the general texture of the embryo, in having a darker colour, in containing no fibres, in separating readily from the surrounding parts, and in their lobulated appearance. They extend forwards nearly to the base of the cranium, and are not connected across the median plain. They are broadest at the sides of the heart, and when the pericardium is opened, are seen through its posterior wall occupying the future situations of the lungs, which at the period stated exist as two small lobulated white bodies, projecting from the intestinal tube, behind and below the heart.

These two lateral masses are the only remaining portions of the membrana intermedia: the posterior portion on each side, on the inner aspect of the anterior extremity of the Wolffian body, becomes the supra-renal capsule; the enlarged middle portion and the outer part of the cervical portion become the thymus; while the internal anterior part resolves itself into the thyroid body. These three organs are therefore at this period continuous with one another on each side of the middle line, no isthmus having yet been formed. They are also continuous with the Wolffian bodies; these bodies, the supra-renal capsule, the thymus and the thyroid forming a continuous mass, situated in the elongated angular channel, which stretches from the cranium to the coccyx on the outside of the intestinal or mesenteric laminæ, and between them and the visceral laminæ.

The Wolffian bodies are the last organs formed out of the membrana intermedia, which assume a special structure. The supra-renal capsules, the thymus and thyroid, retain throughout their existence the original texture of the blastoderma.

Proceeding therefore in the order of formation as well as of position from the Wolffian body, I shall state very briefly what I have observed concerning the mode of development of the supra-renal capsules, thymus and thyroid.

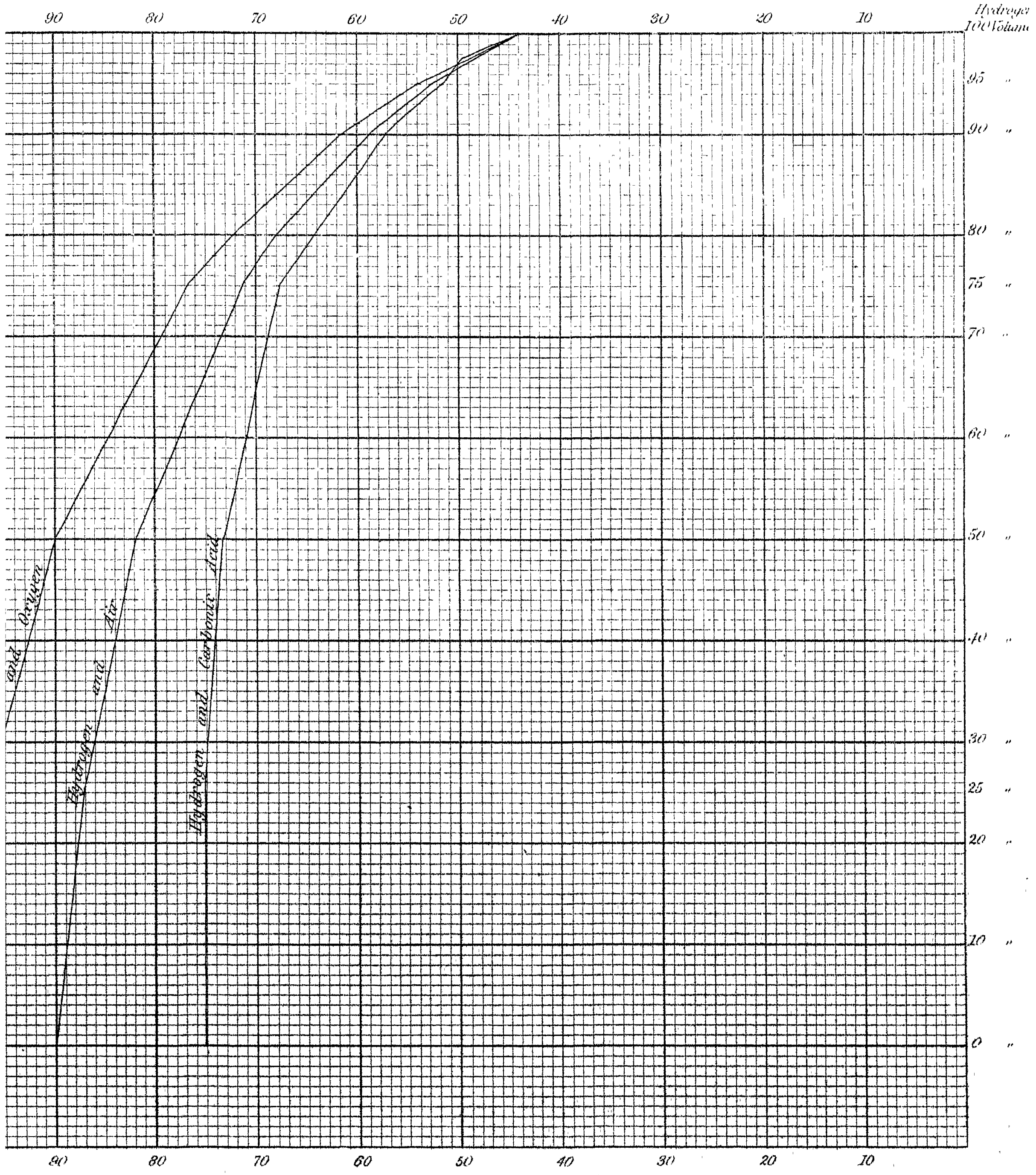
In the embryo of the Sheep, in which the branchial clefts are still quite open, the omphalo-mesenteric vessels well-developed, the liver consisting of an equal-sized lobe on each side of the intestinal tube, the Wolffian bodies well-formed, the allantois beginning to protrude from the abdomen, and the umbilical vessels already apparent, there may be seen between the internal anterior part of the Wolffian bodies and the aorta at the origin of the omphalo-mesenteric arteries, and also around the omphalo-mesenteric vein, where that vessel is passing forward into the liver, a mass of blastema spread over the internal surface of the fore-part of the Wolffian body, and arranged in one or more masses between that gland and the aorta.

In embryos rather more advanced, these masses of blastema become less distinct, apparently from their increased bulk causing them to be applied more uniformly over the anterior extremities of the Wolffian bodies. They may always be detected by their whiter appearance, and by being destitute of the cross markings produced by the ducts of the Wolffian glands.

It is not till the testes, ovaries and kidneys have appeared, that the supra-renal capsules are recognized as distinct organs; and their progress after this period need not be considered further at present.

The cardinal veins of RATHKE pass forward along the posterior and lateral part of the Wolffian bodies; after passing beyond the blunt anterior extremities of these bodies, each vein carries with it, or is covered by a thin layer of the blastema already alluded to, as forming at its posterior part the supra-renal capsule. This portion of the blastema becomes much larger at the side of the heart, round the ductus Cuvieri, behind the lateral parts of the pericardium, and in the future situation of the lungs, which have not yet left their median position. Each lateral portion of the blastema stretches

Transpiration of mixed Gases



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from the heart forwards along the internal side of the jugular vein, par vagum and carotid arteries. These two anterior portions of the lateral blastema, from the narrow portion forwards to the skull, are the lateral portions of the thymus and thyroid, which have not yet joined across the middle line.

In embryos a little further advanced, the two portions of blastema join across the trachea in a line extending from the base of the heart to the lower end of the larynx, which has now appeared as an oblong oval swelling behind the tongue. Previous to, and also contemporaneous with this cross junction, a change has occurred in the position of the lungs and of the ductus Cuvieri.

As the lungs proceed in development, they pass in a direction from behind forwards and from within outwards, moving from their original median position to a lateral one: they at the same time increase both absolutely and relatively. At the same time, a somewhat similar change takes place in the two ductus Cuvieri. They pass forward so as to appear to enter the anterior instead of the posterior extremity of the auricle, becoming in this way the anterior venæ cavæ, this change of position being produced apparently by a semi-revolution of the whole heart, coinciding with its elongation and the altered arrangement of the bulbus aortæ.

Coincident with this change in the ductus Cuvieri is a corresponding change in the position of the lateral masses of the blastema. These pass forward, become grouped around the auricles and anterior venæ cavæ, and join across the middle line as already stated; but a narrow portion, particularly along the left side, still passes downwards and backwards along the cardinal veins, which have now become the azygos veins.

While these changes in the veins and blastema have taken place, the lungs have increased in size, and their roots have taken up their proper position. In consequence of this change in the position of the pulmonary roots and of the ductus Cuvieri, the cardinal veins arch over the root of the lungs in the same manner as the azygos vein of the adult does.

At the same time the blastema of opposite sides unites, as has been stated, across and in front of the base of the heart and root of the neck.

Shortly after this period, the posterior part of the blastema, which has now advanced, as already stated, from the sides of the chest to the front of the heart, becomes separated by a narrow neck from the cervical portion. The posterior part has now become the thoracic portion of the thymus, and in the embryo of the Sheep is largest on the left side, corresponding in this respect to the large size of the left vena azygos and left vena cava at this period.

The cervical portion of the blastema now begins to exhibit a separation into the thyroid and cervical portion of the thymus. This is effected by the absorption of a portion of the blastema, of a triangular form, a little behind the larynx, the apex looking backwards, the concave base forwards, so that the future thyroid present a crescentic form, its sides being as yet united to the anterior horns of the thymus, which pass along the jugular veins.

The thyroid now separates more completely from the thymus, by the prolongation forwards of the absorption previously mentioned from the anterior angles of the triangular portion, so as to separate the thyroid from the anterior horns of the thymus; at the same time the posterior angle of the absorbed portion passing back so as almost again to separate the cervical portion of the thymus into two lateral portions.

As development advances the thyroid becomes more completely separated from the thymus, and the lateral portions of the cervical part of the latter are united only by the narrow portion which connects them with the thoracic lobe of the organ.

At this stage a distinction may be observed, with low magnifying power, in the texture of the two organs. The thyroid is more opake and homogeneous, the thymus consists of minute granular masses imbedded in a semitransparent matrix. The component elements of the texture of the two organs is however identical, namely, simple nucleated cells grouped around dark points, which I am inclined to regard as centres of nutrition. In the thyroid, these groups are separated and connected by a more or less dense highly vascular areolar texture. In the thymus this texture is weak or deficient.

After this period no great change occurs in the thyroid and thymus of the Sheep; the anterior extremities of the horns of the thymus on each side presenting two bulbous enlargements near the base of the skull, close to the ganglions of the vagus. Four minute white cords may now be seen passing into the superior, and two into the inferior border of the thyroid. These are the inferior and superior thyroid arteries, branches respectively from the first and second branchial arteries.

From these observations it would appear that the supra-renal capsules, the thymus and thyroid, are persistent portions of the membrana intermedia of the germinal area of the ovum, retaining throughout their existence their original simple cellular constitution of that portion of the germinal membrane.

I shall now endeavour to explain in how far the observations just detailed appear to me to enable us to trace the functional import and anatomical peculiarities of these organs.

During the first stage of the development of the animal ovum, digestion and respiration—the absorption and preparation of nutriment—are carried on by the blastoderma, a structure consisting of nucleated cells and of vessels.

The cells, of which the blastoderma consists, are the progeny of that previously occupying the germinal spot of the ovum, and are continually reproduced and increased in numbers by the production of others from the nutritive centres, or secondary germinal spots distributed over it.

Materials for the nutrition of the blastoderma are derived from the subjacent yelk. The matter resulting from the solution of a certain number of the secondary blastodermal cells, that is, of the progeny of the primary blastodermal cells, or *nutritive centres*, is employed by the nutrient matter of the remaining secondary or proper blastodermal cells. In this way "pabulum" is afforded for two purposes, the growth of the blastoderma, and the growth of the embryo itself.

During the early period of the existence of the blastoderma, before the circulation has been established, the product of solution of the elder is at once absorbed by the younger cells. During the later periods, the product of solution drops into the incipient loops of the blood-vessels, and so circulates for purposes of nutrition. This is an instance of primary lymphatic absorption, and differs in no essential particular from the same process in the animal further advanced. We may consider the blastoderma in fact, during the first period of its circulation, as containing very numerous lymphatic ducts, instead of a few, as in the more perfect animal.

In the blastoderma, the process by which nutrient matter passes into the circulation, or the act of absorption, as it is usually called, is reduced to its most simple form, being contemporaneous and also identical with the formation of the imperfect capillary network. In the more advanced animal, when the capillary network is consolidated, the product of solution of the textures passes or drops into the intercellular or textural lacunæ, which appear to be the radicles of the lymphatic system; a system which in the adult communicates with the blood-vessels only at a few places in the neighbourhood of the trunks of the original blastodermal veins.

The blastoderma may be considered therefore not only as the first form which the being assumes after the commencement of development, and as a basis out of, and in which its higher structures are to be raised, but also, as has been already stated, the organ of primary digestion; that is, of the appropriation and elaboration by the individual of nutritive matter already prepared, to a certain extent, by another individual or organ.

All the principal organs and parts of the future being are formed in, and out of, portions of the blastoderma. The laminæ dorsales, the cerebro-spinal axis, the visceral laminæ, the intestinal tube, heart and liver, derive their origin from this source. Their original relation to this part is soon lost sight of from changes in their positions, but principally from the increased development of their original blastema, and its change into the various textures, and from the various arrangement of these textures in the organs.

There are three organs however which still retain their primitive structure after all the other parts of the animal have undergone their complete development, so as finally to exhibit no trace of their original simple texture and arrangement. These organs are the supra-renal capsules, the thymus and thyroid.

The structure of each of these three organs is essentially the same: they consist of masses of nucleated cells. These cells are grouped around numerous germinal spots, arranged throughout the mass, and which may be supposed to act as centres of origin and of nutrition, each for its own group. The mass of the organ is supplied with blood-vessels to convey the blood to and from the part, and with lymphatics which receive the product of solution of the cells, and convey it back again into the general circulation, whence it was originally derived.

The account of the structure of the thymus given by Sir Astley Cooper, is so far incorrect, as this organ contains no reservoirs or cavities in its substance. The cavities exhibited by Sir Astley Cooper in his drawings and preparations, are the results of modes of preparing. They are artificial cavities formed by distension, between the somewhat smooth, highly vascular, and slightly adhering outer surfaces of contiguous lobules; the whole organ being at the same time bound together by a stronger external areolar texture. No milky fluid is found naturally in these interlobular spaces. Indeed Sir Astley Cooper says, that "the best mode of obtaining it, is by cutting the gland into very small pieces and placing them upon gauze, which being squeezed, the solid is separated from the fluid part, and the latter escapes through the gauze."

The thymus, from the time it assumes its most perfect structure till it begins to degenerate into fatty substance, consists of lobes connected by areolar fibres, without cavities or ducts, formed of nucleated cells grouped around germinal spots, deriving matter for the formation of their cells from arteries passing into it, and being relieved of its venous blood by returning veins, being plentifully supplied with lymphatics, which do not communicate with the supposed reservoirs, as has been suggested, but appear to take their origin, as in other parts, by intercellular lacunæ, in which the walls seem gradually to lose themselves, as the ducts of the liver are lost among the secreting cells of that organ.

The thyroid body possesses a structure which is essentially the same as that of the thymus. It differs from the thymus in not being divided into lobules, in having the groups of cells of which it consists separated from one another by moderately strong capsular membranes, and in being more vascular, the anterior and venous trunks being much larger.

The supra-renal capsules also consist of nucleated cells grouped round germinal spots, and arranged, not in lobules, but in columns passing towards the surface of the organs; an arrangement corresponding to the radiating direction of the veins, and the converging arteries of these parts. The supra-renal and thyroid bodies are more vascular than the thymus from being developed around large arteries, while the thymus is in connection with smaller trunks, the former being developed in connection with the first and second aortic arches and the omphalo-mesenteric vessels; the latter in connexion with the internal mammary arteries and other small thoracic and cervical branches. The greater density of the areolar capsule of the thyroid may probably be explained by this increased vascular supply.

That portion of the membrana intermedia which is separated from the rest of the membrane, and included in the body of the embryo, by the umbilical constriction, and which has not already been devoted to the formation of the heart, liver, pancreas and external portion of the intestinal canal, is found massed along the trunks of the primitive venous system, the sides of the arches of the aorta, the terminal portion of that vessel, and the origins of the omphalo-mesenteric arteries.

The portions of the membrana intermedia which are last of being converted into special organs, the Wolffian bodies, are the parts which project one on each side of the aorta, along the posterior part of the cardinal veins of Rathke, between the intestinal plates and visceral laminæ.

The portions of the membrana intermedia which remain between the upper extremities of the Wolffian bodies, and the heart and liver, and which surround the origins of the omphalo-mesenteric arteries, do not become converted into organs of special structure, but retain during life the original constitution of the membrana intermedia of the blastoderma, and increase rapidly in the embryo, constituting the supra-renal capsules. Whatever doubt may be entertained as to the exact functional import of these bodies, the identity of their anatomical constitution with that of the blastoderma is sufficiently evident, and their morphological signification appears to be equally so.

That portion of the membrana intermedia which is situated between those two aortic arches, the extremities of which become the carotid and subclavian arteries, remains during life as the thyroid body. It receives its blood from the first and second aortic arches by two large trunks on each side, the superior and inferior thyroid arteries.

That portion of the membrane which passes in two parts from near the base of the cranium back as far as the ductus Cuvieri and anterior portions of the veins of Rathke, and which are united and concentrated in front of the heart by passing from behind forwards, in harmony with corresponding motions of the neighbouring part, becomes the thymus.

The structure of these three organs is identical with that of the blastoderma. Their probable function, namely, to prepare by the action of their nucleated cells, and to throw into the vascular system a matter necessary for the nutrition of the animal during the period of its active growth—a function which the observations and opinions of the majority of physiologists have assigned to them—is also essentially the same with that of the blastoderma.

The question as to the exact or intimate nature of the function of these organs can only be answered by further inquiries in chemical physiology. It appears to me to be sufficient at present to insist, that their functions, as deduced from their structure and anatomical relations, is similar to that performed by the blastoderma, whatever the exact nature of that function may be.

I have therefore been led to consider the supra-renal capsules, the thymus and thyroid, as organs essentially similar in structure; as developments of the remains of the blastoderma, being formed of a continuous portion of that part situated along each side of the spine, from the Wolffian bodies to the base of the cranium, the supra-renal capsules being developed in connection with the omphalo-mesenteric vessels, the thymus to the jugular and cardinal veins, and ductus Cuvieri; and the thyroid to the anastomosing branches of the first and second aortic arches, as organs performing functions, whatever these may be, analogous to those of the blastoderma, differing from them only in this, that the blastoderma not only elaborates nourishment for the embryo, but absorbs it also from without, that is, from the yelk; whereas the three organs in question only elaborate the matter which has already been absorbed by the other parts, and is now circulating in the vessels of the more perfect individual.

Description of the Plate.

PLATE XXXVI.

Fig. 1. A portion of an early embryo of the Sheep.
a. Heart.
b. Lungs still in front of the intestinal tube.
c. Wolffian body.
d. Lateral mass of blastema, out of which is formed the supra-renal capsule, thymus and thyroid.
e. Cardinal vein.
f. Jugular vein.
g. Ductus Cuvieri.

Fig. 2. A portion of the early embryo of the Sheep.
a. Intestinal tube and ductus vitelli.
b. Liver.
c. Omphalo-mesenteric vein.
d. Omphalo-mesenteric artery.
e.f. Mass of blastema on the inner side of the Wolffian body, and around the trunks of the omphalo-mesenteric vessels; this is the posterior part of the lateral mass of blastema marked *d* in fig. 1, and becomes in the course of development the supra-renal capsule.

Fig. 3. An early embryo of the Sheep.
a. Head, branchial arches, and rudiment of the eye.
b. Heart.
c. Ductus Cuvieri entering the auricle, and receiving
d. The jugular, and
e. The cardinal vein.
f. The lateral blastema.
g. Wolffian body.
h. Umbilical cord, to which is passing

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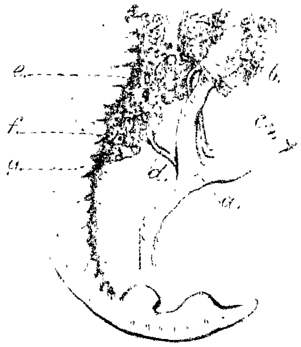

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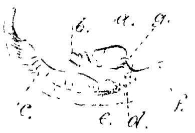

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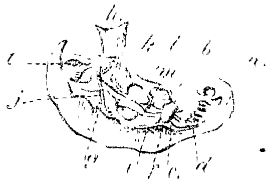

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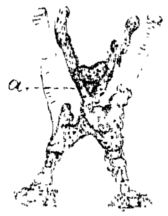

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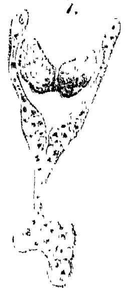

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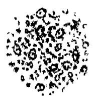

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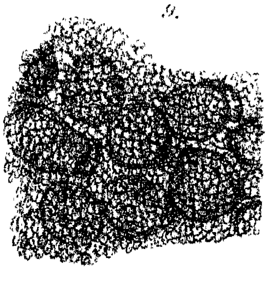

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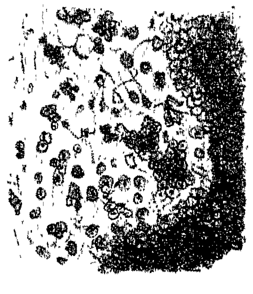

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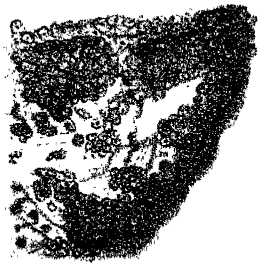

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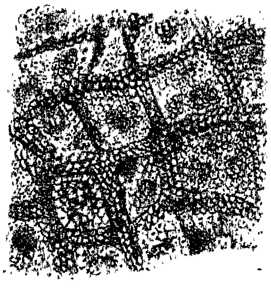

i. The allantois,

j. The omphalo-mesenteric artery, and

k. Omphalo-mesenteric vein; traces of the umbilical vessels are also seen in the parietes of the abdomen.

l. The liver and intestinal tube.

m. Lungs.

Fig. 4. Jugular veins and lateral masses of blastema in the Sheep, soon after the latter have joined across the middle line.

a. The triangular absorption of the cervical portion, which is the first indication of the separation of the thyroid.

Fig. 5. The next stage, in which the thyroid is more distinct.

Fig. 6. The thyroid is now quite distinct and differs from the thymus in being opake; the latter exhibits opake spots in a semitransparent matrix.

Fig. 7. The thyroid and thymus have assumed their perfect form.

Fig. 8. A portion of the supra-renal capsule of the adult green Monkey, slightly compressed. It exhibits the minute nucleated particles of which it consists. Among these, at pretty regular distances, are seen the germinal spots.

Fig. 9. A portion of the thymus of the Brown Bear, slightly compressed. It exhibits the nucleated particles of which it consists. These are grouped in spherical masses around centres from which they appear to have derived their origin.

Fig. 10. A portion of the thymus from a human fœtus. It has been taken from the surface of the gland, so as to exhibit the areolar fibres which form its delicate capsule. The pressure of the glass plates has almost obliterated the spherical grouping of the cells.

Fig. 11. A portion of the membrane which covered the contiguous surfaces of the lobes of the thymus of a human fœtus (the membrane lining the reservoirs of Sir A. Cooper). It has the same structure as in fig. 10. It exhibits no germinal membrane, but consists of an areolar or fibrous texture intermixed with the cells of the organ, the fibres being more fasciculated, and running a straighter course than in the substance of the organ.

Fig. 12. A portion of the thyroid from a human fœtus, slightly compressed. It exhibits the same structure as the thymus, but its fibrous texture is more developed.

Fig. 13. A portion of the same thyroid to show its vascular net-work, in the meshes of which, as in fig. 12, the cells are seen arranged in groups.

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30th NOVEMBER, 1846.

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⁂ *This Council will continue till November* 30, 1847.

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NOVEMBER 30, 1846.

(C) prefixed to a name indicates that the Member has received a Copley Medal.
(R) ... ... Royal Medal.
(Rm) ... ... Rumford Medal.
(P) ... ... has contributed a Paper to the Philosophical Transactions.
(*) ... ... is liable to an annual payment of £2 12*s*.
(†) ... ... is liable to an annual payment of £4.

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1808. Apr. 28.			Aberdeen, George, Earl of, K.T. Trust. Brit. Mus. F.L.S. *Argyll-house.*
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1845. June 5.		†	Adair, Robert Shafto, Esq. 7 *Audley-square.*
1834. Apr. 10.			Adare, Edwin, Viscount, F.R.A.S. *Adare-abbey, Limerick; Dunraven-castle, Glamorganshire.*
1846. Jan. 29.	P.	†	Addison, William, Esq., F.L.S. *Great Malvern.*
1832. June 7.		†	Agar, Hon. George Charles, M.A. *University Club.*
1836. Jan. 21.	C.R. P.		Airy, George Biddell, Esq., M.A., D.C.L., Astronomer Royal. V.P.R.A.S.—Hon. Mem. R.S.E. R.I.A. R.I.S.W. F.C.P.S., Corresp. Mem. National Inst. Washington U.S. Inst. Reg. Sc. Paris., Acadd. Imp. Sc. Petrop., et Reg. Sc. Berol. Corresp., Acadd. Sc. Lit. Panorm., Holm. et Monach. Socc. Reg., Sc. Hafn.. Acad. Amer. Art. et Sc. Bost. Socius. *The Royal Observatory, Greenwich.*
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1844. Jan. 11.		†	Ansted, David Thomas, Esq., M.A., Professor of Geology, King's College, London. Vice-Sec. Geological Society. 28 *Sackville-street.*
1840. Nov. 26.		†	Archibald, Charles Dickson, Esq., F.S.A., F.G.S. M.R.I. 3 *York-terrace, Regent's-park; and Rutland-hall, Lancashire.*
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1814. June 30.		Beaufort, Francis, Rear Admiral, F.G.S. F.R.A.S. Instit. Sc. Paris. Corresp. *Admiralty; and* 11 *Gloucester-place, Portman-square.*
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1835. Feb. 5.		† Beetham, Albert William, Esq., F.S.A. 6 *Serjeant's-inn, Fleet-street; and Ropehill-lodge, Bolder, near Lymington, Hants.*
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1841. Dec. 16.		† Bennett, John Joseph, Esq., Sec. L.S. *British Museum.*
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1827. May 10.		Bicheno, James Ebenezer, Esq., F.L.S. F.G.S. Colonial Secretary, Van Diemen's Land. *Hobart Town.*
1844. June 6.		† Billing, Archibald, M.D. Coll. Reg. Med. Socius, Soc. Med. Nov.-Ebor. Socius, Soc. Med.-Phys. Florent. et Med.-Chir. Brux. Corresp. 6 *Grosvenor Gate, Park-lane.*
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1842. Nov. 17.	P.	Bowerbank, James Scott, Esq., F.G.S. 45 *Park-street, Islington.*
1841. Apr. 22.	R.P.	Bowman, William, Esq. 14 *Golden-square.*
1809. Apr. 13.	C.P.	Brande, William Thomas, Esq., Professor of Chemistry in the Royal Institution, F.R.S.E. *Royal Mint, Tower-hill.*
1821. Mar. 8.		Brandreth, Thomas Shaw, Esq. *University-club.*
1841. Jan. 21.		† Brandreth, Henry Rowland, Major R.E. *Somerset-house.*
1834. June 5.		† Breadalbane, John Campbell, Marquis of. 21 *Park-lane; and Taymouth-castle, Aberfeldie.*

Date of Election.		
1815. May 4.	C. Rm. R.P.	Brewster, Sir David, K.H. LL.D. F.R.S.E. Hon. M.R.I.A. F.G.S. F.R.A.S. Instit. Reg. Sc. Paris. Corresp.—Soc. Reg. Sc. Gotting. Socius. Principal of St. Leonard's College. *St. Andrew's.*
1821. Mar. 15.		Bridgman, William, Esq., F.S.A. F.L.S. *Frogmore, Gloucester.*
1838. Nov. 22.		† Briggs, Major-General John, E.I.C.S. M.R.A.S. F.G.S. 3 *Charles-street, St. James's.*
1821. Mar. 8.		Bright, Richard, M.D. Coll. Reg. Med. Socius, F.G.S. Soc. Reg. Med. Hafn. Socius.—Acad. Sc. Sien., Socc. Erud. Hung., et Medico-Chir. Berolin. Corresp. 11 *Saville-row.*
1810. May 10.		Brisbane, Lieut.-General Sir Thomas Macdougall, Bart. K.C.B. G.C.H. D.C.L. President of the Royal Society of Edinburgh, Hon. M.R.I.A. F.R.A.S. F.L.S. Instit. Reg. Sc. Paris. Corresp. *Makerstown, Kelso.*
1805. May 23.		Bristol, Frederick William, Marquis of. 6 *St. James's-square; and Ickworth-park, Bury St. Edmunds.*
1834. Dec. 18.		† Brockedon, William, Esq. 29 *Devonshire-street, Queen's-square.*
1828. Feb. 14.		Broderip, William John, Esq., B.A. F.L.S. F.G.S. 2 *Raymond-buildings, Gray's-inn.*
1810. Feb. 15.	C.P.	* Brodie, Sir Benjamin Collins, Bart. Serjeant Surgeon to the Queen. Inst. Reg. Paris. Corresp. 14 *Saville-row.*
1817. Mar. 13.		Bromhead, Sir Edward Ffrench, Bart. M.A. F.R.S.E. F.R.A.S. *Thurlby, Lincolnshire.*
1823. May 29.		Brooke, Sir Arthur Brooke de Capell, Bart. M.A. F.L.S. F.G.S. *Okeley, Northamptonshire.*
1819. Apr. 22.		Brooke, Henry James, Esq., F.L.S. F.G.S. *Clapham-rise.*
1803. Mar. 3.	P.	Brougham and Vaux, Henry, Lord, M.A. Instit. Reg. Sc. Paris. Socius. 4 *Grafton-street; and Brougham-hall, Penrith.*
1842. Feb. 17.		† Broughton, Robert Edwards, Esq. 1 *Melcombe-place.*
1811. Dec. 12.	C.	Brown, Robert, Esq., D.C.L. Hon. Mem. R.S.E., R.I.A., Med.-Chirurg. S., and C.P.S. V.P.L.S. Instit. Reg. (Acad. Scient.) Paris. Socius.—Acadd. Reg. Scient. Berol., et Taurin., Imp. Sc. Petrop., Reg. Sc. Holm., Monach., Neapol., Bruxell. et Bonon., Instit. Reg. Sc. Amstelod., Socc. Reg. Sc. Hafn., et Upsal., Acad. Cæs. Nat. Cur., Socc. Sc. Harlem., Trajectin., Phys. et Hist. Nat. Genev., Imp. Hist. Nat. Mosc., Nat. Scrutat. Berolin., Wetter., Phil. Nov.-Ebor., Med. et Phys. Bengal., et Med. Holm. Socius. 17 *Dean-street, Soho.*
1838. May 8.		Brownlow, John, Earl, D.C.L. F.S.A. F.L.S. F.G.S. M.R.A.S. 12 *Belgrave-square; and Belton-house, Grantham.*
1829. Mar. 18.		Bruce, Right Hon. Sir James Lewis Knight, Knt. F.S.A. Vice-Chancellor. *Roehampton Priory.*
1830. June 10.		Brunel, Isambard Kingdom, Esq. 18 *Duke-street, Westminster.*
1814. Mar. 24.		Brunel, Sir Mark Isambard, Knt., Instit. Reg. Sc. Paris., et Acad. Reg. Sc. Monach., Corresp.
1833. June 20.		Buccleuch, Walter Francis, Duke of, K.T. D.C.L. F.L.S. *Whitehall-gardens; and Dalkeith-house, Edinburgh.*
1818. Feb. 26.	C.P.	Buckland, Very Rev. William, D.D., Dean of Westminster. F.L.S. V.P.G.S. Instit. Reg. Sc. Paris. Corresp., Acad. Sc. Bonon. Socc. Min. Imp. Petrop. et Cæs. Nat. Cur. Mosc., Socius. *Deanery, Westminster.*

Date of Election.			
1836. Jan. 21.		†	Budd, George, M.D. Coll. Reg. Med. Socius. 20 *Dover-street, Piccadilly; and Caius-college, Cambridge.*
1846. Jan. 29.		†	Buist, George, Esq., D.C.L. *Bombay.*
1840. May 21.		†	Burge, William, Esq. *Leeds.*
1829. Dec. 10.			Burlington, William, Earl of, M.A. Chancellor of the University of London.—F.G.S. 10 *Belgrave-square; and Hardwick-hall, Derbyshire.*
1835. April 2.			Burnes, James, K.H. D.C.L. *India.*
1837. Mar. 16.		†	Burnet, John, Esq. *Egmont-house, Kensington.*
1838. May 3.		†	Burnet, Rev. Thomas, D.D., Rector of St. James, Garlickhythe. 13 *Finsbury-sq.*
1833. Apr. 18.	P.	†	Burnett, Sir William, K.C.H. M.D. Coll. Reg. Med. Socius.—Acad. Med. et Chir. Petrop. Socius Honor. 5 *Somerset-place.*
1814. Dec. 22.			Burney, Rev. Charles Parr, D.D. F.S.A. F.L.S. F.G.S. F.R.A.S. M.R.A.S. M.R.S.L. *Rectory-house, Sible Hedingham, near Halsted, Essex.*
1829. April 1.			Burns, John, M.D. *Glasgow.*
1818. Feb. 26.			Burrow, Rev. Edward John, D.D. F.G.S. *Gibraltar.*
1836. Mar. 17.			Burt, Major T. Seymour, M.R.A.S. *India.*
1832. Dec. 6.			Burton, Decimus, Esq., F.S.A. 6 *Spring-gardens; and St. Leonard's, Hastings.*
1836. May 5.		†	Burton, Edward, Esq., F.L.S. *Brooklyn, near Maidstone.*
1844. Feb. 1.		†	Bury, Edward, Esq. *Wolverton.*
1818. Jan. 8.			Bute, John, Marquis of, D.C.L. F.S.A. F.R.A.S. *Camden-hill, Kensington; and Cardiff Castle, Glamorganshire.*
1819. May 20.			Butler, The Very Rev. George, D.D. Dean of Peterborough, F.S.A. F.R.A.S.
1822. Mar. 21.			Butter, John, M.D. F.L.S. *Plymouth; and Corringdon-hall, South Brent, Devonshire.*
1841. May 6.		†	Byng, Right Hon. George Stevens. 77 *Eaton-square.*
1837. Jan. 19.			Cabbell, Benjamin Bond, Esq., F.S.A. 1 *Brick-court, Temple.*
1810. June 28.			Cadell, William Archibald, Esq., F.R.S.E. F.G.S. *Edinburgh.*
1831. Mar. 10.	P.		Caldcleugh, Alexander, Esq., F.L.S. F.G.S. *Chili.*
1840. Feb. 20.			Caldecott, John, Esq., F.R.A.S. *Observatory, Travancore, India.*
1796. Nov. 17.			Canterbury, Right Hon. William Howley, D.D., Lord Archbishop of, Trust. Brit. Mus. F.S.A. M.R.S.L. *Lambeth-palace.*
1839. Feb. 14.		†	Carington, Robert John, Lord. *Whitehall-yard; and Wycombe-abbey and Gayhurst, Bucks.*
1826. Feb. 9.			Carleton, Hon. and Rev. Richard, M.A. *Greywell-hill, Odiham, Hampshire.*
1814. May 19.			Carlisle, Nicholas, Esq., K.H. D.C.L. Hon. M.R.I.A. Sec. A.S. Soc. Reg. Antiq. Septen. Hafn., et Acad. Reg. Sc. Holm. Socius, Acad. Sc. et Lit. Panorm. Corresp. *Somerset-house.*
1818. May 28.	P.		Carne, Joseph, Esq., M.R.I.A. F.G.S. *Penzance.*
1844. Feb. 1.		†	Carpenter, William Benjamin, M.D. 1 *Clarence-terrace, Stoke Newington.*
1800. Dec. 18.			Carrington, Sir Codrington Edmund, Knt. D.C.L. F.S.A. M.R.A.S. 32 *Russell-square.*
1841. Feb. 11.			Cartwright, Samuel, Esq., F.L.S. 32 *Old Burlington-street.*
1846. Apr. 2.		†	Cautley, Proby T., Major, F.G.S. 39 *Lower Grosvenor-street.*
1812. June 11.			Cawdor, John Frederick, Earl, Trust. Brit. Mus. F.G.S. 74 *South Audley-street; and Cawdor-castle, Nairn.*

Date of Election.			
1828. Mar. 13.			Chambers, William Frederick, M.D. K.C.H. Physician to the Queen. Coll. Reg. Med. Socius. 46 *Brook-street.*
1833. Feb. 7.		†	Chandler, Very Rev. George, Dean of Chichester, D.C.L. M.R.S.L. R.G.S. 36 *Mortimer-street.*
1816. Nov. 21.			Chapman, Major-Gen. Sir Stephen Remnant, C.B. K.C.H. R.E. *Tainfield-house, Taunton, Somerset.*
1836. Apr. 28.		†	Chapman, John James, Esq., Capt. R.A. *Athenæum Club.*
1842. May 26.			Chapman, Thomas, Esq., F.S.A. 14 *Montagu-place; and Whitby, Yorkshire.*
1834. Feb. 6.			Chesney, Lieut.-Colonel Francis Rawdon, R.A. 11 *Wilton-terrace, Grosvenor-place.*
1807. Mar. 12.	P.		Children, John George, Esq., F.R.S.E. F.S.A. F.L.S. 48 *Torrington-square.*
1826. Jan. 12.	P.		Christie, Samuel Hunter, Esq., M.A.—SECRETARY.—V.P.R.A.S. F.C.P.S., Professor of Mathematics, Royal Military Academy. Acad. Sc. et Lit. Panorm., et Soc. Philom. Paris. Corresp. *Royal Military Academy, Woolwich.*
1842. Apr. 14.		†	Christmas, Rev. Henry, M.A. F.S.A. *Sion College, London Wall.*
1833. Apr. 18.			Christopher, Robert Adam Dundas, Esq. 97 *Eaton-square.*
1818. Dec. 10.			Churchill, Francis Almaric, Lord. *Cornbury-park, near Witney, Oxfordshire.*
1832. June 7.			Clark, Sir James, Bart. M.D. Physician to the Queen. 22 *B, Brook-street.*
1836. Jan. 28.		†	Clark, William, M.D. *Cambridge.*
1837. May 11.		†	Clark, William Tierney, Esq. *Hammersmith.*
1825. June 9.			Clarke, Sir Charles Mansfield, Bart. M.D., Coll. Reg. Med. Socius. *Wigginton-lodge, Tamworth; and* 14 *New Burlington-street.*
1820. May 18.			Clarke, Loftus Longueville, Esq., M.A. *India.*
1841. Feb. 18.		†	Clendinning, John, M.D. Coll. Reg. Med. Socius. 16 *Wimpole-street.*
1819. May 27.			Clerk, Right Hon. Sir George, Bart. D.C.L. M.P. F.R.S.E. F.G.S. 8 *Park-street, Westminster.*
1833. Apr. 18.		†	Clerke, Major Thomas Henry Shadwell, K.H. R.E. F.R.A.S. 4 *Brompton-grove.*
1823. May 8.	P.		Clift, William, Esq., F.G.S. *Royal College of Surgeons, Lincoln's-inn-fields.*
1820. Dec. 21.			Cockburn, Vice-Admiral Right Hon. Sir George, G.C.B. G.C.H. F.R.A.S.
1822. Nov. 21.			Codrington, Vice-Admiral Sir Edward, G.C.B. *Admiralty-house, Portsmouth; and Hampton-lodge, Brighton.*
1820. Apr. 13.			Colby, Major-General Thomas, R.E. LL.D. F.R.S.E. Hon. M.R.I.A. F.G.S. F.R.A.S. M.R.A.S. *Ordnance Map Office, Southampton.*
1830. Feb. 18.			Collier, Charles, M.D. F.G.S. 20 *Fitzroy-square.*
1830. Jan. 14.		†	Colquhoun, Lieut.-Colonel James Nisbet, R.A. *Athenæum Club.*
1819. Dec. 9.			Conybeare, Very Rev. William Daniel, Dean of Llandaff, M.A. F.G.S. Instit. Reg. Sc. Paris. Corresp. *Deanery, Llandaff.*
1840. June 4.		†	Cook, Thomas, Esq., Lieut. R.N., Professor of Fortification, E.I.C. Military Academy. *Addiscombe.*
1829. June 18.	P.		Cooper, Bransby Blake, Esq. 2 *New-street, Spring-gardens.*
1832. Dec. 6.			Cooper, Charles Purton, Esq., LL.D. Hon. M.R.I.A. 7 *New Boswell-court, Lincoln's-inn.*
1846. Feb. 5.		†	Cooper, Samuel, Esq. 7 *Woburn-place.*
1834. Feb. 6.			Copeland, Thomas, Esq. 17 *Cavendish-square.*
1833. Dec. 5.		†	Copland, James, M.D. Coll. Reg. Med. Socius, Soc. Amer. Philad. Socius. 5 *Old Burlington-street.*

Date of Election.		
1821. May 24.		Cotton, William, Esq., F.S.A. 3 *Crosby-square, Bishopsgate-street; and Walwoo house, Leytonstone.*
1836. May 5.		† Cox, William Sands, Esq. *Birmingham.*
1812. Apr. 16.		Crampton, Sir Philip Cecil, Bart. D.C.L. *Dublin.*
1818. May 7.		Crawford, John, Esq., F.L.S. F.G.S. M.R.A.S.
1842. Dec. 22.		Creuze, Augustin F. B., Esq. 14 *Grosvenor-place, New-road, Kennington.*
1800. May 8.		* Crichton, Sir Alexander, Knt. M.D. Grand Cross of St. Ann and St. Vladimi F.L.S. F.G.S. Acad. Imp. Sc. Petrop., et Soc. Imp. Hist. Nat. Mosc., Socius.– Soc. Reg. Sc. Gotting. Corresp. *Seal Chart, near Sevenoaks, Kent.*
1818. Mar. 5.		Croft, Sir John, Bart. K.T.S. D.C.L. Acad. Reg. Olyssip. Socius. *Milgat near Maidstone.*
1810. July 5.		Croker, Right. Hon. John Wilson, LL.D.
1836. Feb. 18.		† Crosse, John Green, M.D. Acad. Reg. Med. Paris., Soc. Reg. Med. Hafn. Mec Chir. Berolin., Soc. Amer. Philad. Socius. *Norwich.*
1843. Dec. 7.	P.	† Crozier, Francis Rawdon Moira, Esq., Capt. R.N.
1844. Feb. 29.		Crum, Walter, Esq. *Thornlie Bank, near Glasgow.*
1830. Apr. 1.		Cubitt, William, Esq., M.R.I.A. F.R.A.S. 6 *Great George-street, Westminster.*
1807. Jan. 22.		Cuming, Lieut.-General Hon. John Leslie.
1816. Jan. 11.		Cumming, Rev. James, M.A., Professor of Chemistry, Cambridge, F.G. *Cambridge.*
1838. Jan. 25.		† Cureton, Rev. William, M.A. 37 *Queen Anne-street; and British Museum.*
1841. May 27.		Cursetjee, Ardaseer, Esq. *Bombay.*
1834. Feb. 6.		† Cust, Hon. Sir Edward, K.C.H. 30 *Hill-street.*
1828. June 5.		† Daniell, Edmund Robert, Esq. *Birmingham.*
1822. Nov. 7.		Dartmouth, William, Earl of, D.C.L. F.S.A. 23 *St. James's-square; and Sandwell park, Birmingham.*
1834. Jan. 29.	P.	Darwin, Charles, Esq., M.A. Sec. G.S. *Down, near Bromley Kent.*
1788. Feb. 21.	P.	Darwin, Robert Waring, M.D. *Shrewsbury.*
1822. Dec. 19.	P.	Daubeny, Charles Giles Bridle, M.D., Aldrich's Professor of Chemistry, and Regiu Professor of Botany, Oxford. Hon. M.R.I.A. F.L.S. F.G.S. Coll. Reg. Med Socius. *Oxford.*
1839. May 30.		† Davenport, Edward Davies, Esq. 28 *Lower Brook-street; and Capesthorne Cheshire.*
1831. June 16.		Davies, Griffith, Esq. 25 *Duncan-terrace, City-road.*
1833. Apr. 18.	P.	Davies, Thomas Stephens, Esq., F.R.S.E. F.S.A. *Royal Military Academy Woolwich.*
1841. May 20.		† Davis, Hart, Esq. 17 *Oxford-square, Hyde-park.*
1822. Mar. 28.		Davis, Sir John Francis, Bart. *Portland-place; and Hollywood, near Compton Bristol.*
1826. Jan. 19.	P.	Davy, Edmund, Esq., Prof. of Chemistry to the Royal Dublin Society, M.R.I.A *Dublin.*
1814. Feb. 17.	P.	Davy, John, M.D. F.R.S.E. Inspector-General of Army Hospitals. *Barbadoes and Ambleside, Westmoreland.*
1815. Mar. 9.		Dawkins, James Colyer, Esq., F.S.A. *Ham-common, Richmond.*
1811. Feb. 28.		Dealtry, Rev. William, D.D. F.R.A.S. *Clapham-common.*

De la Beche, Sir Henry Thomas, Knt.—Vice-President—.F.L.S. F.G.S., Director-General of the Geological Survey of the United Kingdom. *Museum of Economic Geology, 6 Craig's-court, Charing-cross.*

† Denham, Henry Mangles, Esq., Commander R.N. 89 *Pall Mall; and Port Fleetwood.*

† Denham, Rev. Joshua Frederick, M.A. 1 *New Inn.*

Denison, Sir William Thomas, Capt. R.E. F.R.A.S. F.R.G.S. Lieut. Governor, Van Diemen's-Land.

† Denman, Thomas, Lord. 38 *Portland-place; and Stoney Middleton, Derbyshire.*

D'Eyncourt, Right Hon. Charles Tennyson, F.S.A. 35 *Pall Mall.*

† Dickenson, John, Esq., F.G.S. F.R.G.S. F.A.S. *Abbott's-hill, Hemel Hempstead.*

P. Dillwyn, Lewis Weston, Esq., F.L.S. F.G.S. *Sketty-hall, near Swansea.*

† Disney, John, Esq., F.S.A. *The Hyde, near Ingatestone, Essex.*

Dixon, Rev. Richard, M.A. *Niton, Isle of Wight.*

† Dobson, Sir Richard, Knt. *Royal Hospital, Greenwich.*

P. Dollond, George, Esq., F.R.A.S. 59 *St. Paul's Churchyard; and North-terrace, Camberwell.*

† Donkin, Bryan, Esq., F.R.A.S. 6 *Paragon, Kent-road.*

† Donkin, William Fishburn, Esq., M.A., Savilian Professor of Astronomy in the University of Oxford. *Oxford.*

Douglas, George, Esq. *Chilston, Kent.*

* Douglas, Major-General Sir Howard, Bart. C.B. K.S.C. D.C.L. F.S.A. 15 *Green-street, Grosvenor-square.*

Douglas, Lord William Robert Keith.

† Drory, George William, Esq. 38 *Westbourne-terrace, Hyde-park.*

† Drummond, Henry, Esq. *Albury-park, Guildford, Surrey.*

Duckett, Sir George, Bart. M.A. F.S.A. F.G.S. Hon. M.R.I.S.

D'Urban, Major-General Sir Benjamin, K.C.B. K.C.H. K.T.S.

Durham, Edward Maltby, D.D. Lord Bishop of, F.S.A. 4 *Upper Portland-place; and Auckland-castle, Durham.*

East, Right Hon. Sir Edward Hyde, Bart. M.R.A.S. *Palladium-office, Waterloo-place; and Sherwood-lodge, Battersea.*

† Eastlake, Charles Locke, Esq., R.A. 13 *Upper Fitzroy-street.*

† Edye, John, Esq. 9 *Mecklenburgh-square.*

† Edye, Joseph, Esq. *Portsmouth.*

Egerton, Sir Philip de Malpas Grey, Bart. F.G.S. 30 *Eaton-place; and Oulton-park, Cheshire.*

Elliot, Sir William Francis, Bart. *Stobb's-castle; and Wales, N B.*

Elliot, Hon. George, Capt. R.N.

Elliotson, John, M.D. Coll. Reg. Med. Socius. 37 *Conduit-street.*

† Elliott, Charles, Esq. 47 *Portland-place.*

Elliott, Rev. Charles Boileau, M.A. 47 *Portland-place; and Tattingstone, Suffolk.*

* Ellis, Sir Henry, K.H. D.C.L. Sec. S.A. Hon. M.R.I.A. Hist. Scand. Holm. et Soc. Reg. Antiq. Hafn. Socius.—Soc. Reg. Antiq. Franc. Corresp. Principal Librarian of the British Museum. *British Museum.*

Ellis, Right Hon. Henry, F.G.S.

Date of Election.			
1801. Mar. 12.			Ellis, John, Esq., F.L.S.
1832. June 7.		†	Elphinstone, Howard, Esq., M.A. F.G.S. 19 *Eaton-place, Belgrave-square.*
1841. Jan. 14.			Enderby, Charles, Esq., F.L.S. *Greenwich.*
1829. Jan. 15.			Enniskillen, William Willoughby, Earl of, D.C.L. F.G.S. *Athenæum Club; and Florence-court, Fermanagh, Ireland.*
1827. Mar. 8.			Everest, Lieut.-Colonel George, Bengal Artillery, F.G.S. F.R.A.S. M.R.A.S. Surveyor-General of India. 16 *Bury-street, St. James's.*
1840. May 21.		†	Ewer, Walter, Esq. 23 *Hanover-square.*
1845. Feb. 13.		†	Falconer, Hugh, M.D. F.L.S. F.G.S. *Oriental Club, Hanover-square.*
1824. Jan. 8.	C. Rm. R.P.		Faraday, Michael, Esq., D.C.L., Fullerian Professor of Chemistry in the Royal Institution of Great Britain. Hon. Mem. R.S.E., and C.P.S. F.G.S. Instit. Reg. (Acad. Sc.) Paris. Socius, Acad. Imp. Sc. Petrop. Socius Honor.—Acad. Reg. Sc. Holm., Soc. Reg. Sc. Hafn., Acad. Reg. Sc. Mut., Acad. Amer. Art. et Sc. Bost. Socius, Acad. Reg. Sc. Berol., Soc. Georg. Florent., Soc. Philom. Paris., et Acad. Reg. Med. Paris. Corresp. 21 *Albemarle-street.*
1839. May 2.	P.	†	Farre, Arthur, M.D. Coll. Reg. Med. Socius. 22 *Curzon-street, May-fair.*
1835. April 2.		†	Featherstonhaugh, G. W., Esq. *Havre.*
1816. Feb. 29.			Fellowes, Sir James, Knt. M.D. Coll. Reg. Med. Socius. *Pangbourne-lodge, near Reading.*
1836. Mar. 3.			Field, Joshua, Esq. *Cheltenham-place, Lambeth.*
1842. May 5.		†	Fielding, George Hunsley, M.D. *Ashford, Kent.*
1825. Jan. 27.	P.		Fisher, Rev. George, M.A. F.R.A.S. *Royal Hospital, Greenwich.*
1815. Nov. 9.			Fitton, William Henry, M.D. F.L.S. F.G.S. F.R.A.S. Coll. Reg. Med. Socius. 53 *Upper Harley-street.*
1811. Jan. 17.			Fitzwilliam, Charles William, Earl, F.S.A. F.G.S. *Mortimer-house, Grosvenor-place; and Wentworth-house, near Rotherham, Yorkshire.*
1839. Mar. 21.			Fletcher, Thomas William, Esq., F.S.A. *Dudley, Worcestershire.*
1834. Apr. 10.		†	Folkes, Sir William Browne, Bart. *Hillington-hall, Lynn.*
1845. Feb. 13.		†	Forbes, Edward, Esq., F.L.S. F.G.S. Professor of Botany at King's College. Palæontologist to the Geological Survey of Great Britain. *King's College.*
1832. June 7.	Rm. R.P.		Forbes, James David, Esq., Professor of Natural Philosophy in the University of Edinburgh. Sec. R.S.E. F.G.S. Instit. Reg. Sc. Paris. Corresp. *Edinburgh.*
1829. Feb. 5.			Forbes, John, M.D. Coll. Reg. Med. Socius. 12 *Old Burlington-street.*
1822. Feb. 21.			Forbes, William Nairn, Esq., F.G.S.
1828. June 12.		†	Forshall, Rev. Josiah, M.A. F.S.A. Hon. M.R.I.A. M.R.S.L. *British Museum.*
1821. Feb. 22.			Forster, Edward, Esq., V.P.L.S. 11 *Mansion-house-street; and Woodford, Essex.*
1817. June 5.			Fortescue, Hugh, Earl. 17 *Grosvenor-square; and Castle-hill, Southmolton.*
1802. April 1.			Fowler, Richard, M.D. F.S.A. *Salisbury.*
1845. Feb. 13.	P.		Fownes, George, Esq., Professor of Practical Chemistry, University College, London.
1823. Feb. 20.			Franklin, Sir John, Knt. Capt. R.N. D.C.L. F.L.S. V.P.R.G.S. F.G.S. F.R.A.S. Acad. Scient. Paris. et Soc. Geogr. Paris. Corresp.
1821. Dec. 12.			Franks, William, Esq., M.A. *Wood-hill, Hatfield, Hertfordshire.*
1837. June 8.			Frere, George Edward, Esq. *Roydon-hall, Diss, Norfolk.*
1834. Apr. 10.		†	Freshfield, James William, Esq., F.G.S. 15 *Regent-street; and Leatherhead, Surrey.*
1820. Mar. 16.			Friend, Matthew Curling, Esq., Lieut. R.N. *George Town, Van Diemen's Land.*

Date of Election.			
1839. Jan. 10.		†	Frodsham, William James, Esq. *Change-alley, Cornhill.*
1834. Dec. 18.		†	Galloway, Thomas, Esq., M.A. F.R.A.S. 45 *Torrington-square.*
1816. April 4.			Gardiner, Rev. Samuel John, M.A.
1839. Mar. 21.			Gaskin, Rev. Thomas, M.A. F.R.A.S. *Jesus College, Cambridge.*
1840. April 9.	P.	†	Gassiot, John P., Esq. *Clapham-common.*
1796. Feb. 18.			Gibbes, Sir George Smith, Knt. M.D. F.L.S. Coll. Reg. Med. Socius. 2 *Oriel-place, Cheltenham.*
1846. June 18.		†	Gilbart, James William, Esq., London and Westminster Bank. *Lothbury.*
1834. Apr. 10.			Gilbert, John Davies, Esq., M.A. *Eastbourne, Sussex; and Trelissick, Truro.*
1828. Mar. 27.			Glenelg, Charles, Lord, D.C.L. M.R.S.L. *Glenelg, Inverness.*
1838. Feb. 8.			Glynn, Joseph, Esq. *Butterley, Derbyshire.*
1839. Mar. 7.		†	Godwin, George, jun., Esq., F.S.A. 11 *Pelham-crescent, Brompton.*
1808. May 26.	P.		Goldingham, John, Esq., F.R.A.S. M.R.A.S. *Worcester.*
1828. Mar. 13.			Goldsmid, Baron De, and De Palmeira, F.S.A. F.L.S. F.G.S. F.R.A.S. M.R.S.L. *Park-lodge, Regent's-park.*
1819. Jan. 29.	P.		Gompertz, Benjamin, Esq., F.R.A.S. *Kennington-terrace, Vauxhall.*
1846. June 11.		†	Goodsir, John, Esq., Professor of Anatomy, University of Edinburgh. 21 *Lothian-street, Edinburgh.*
1835. April 2.		†	Gordon, James Alexander, M.D. Coll. Reg. Med. Socius. *Pelican Life Assurance Office, Lombard-street.*
1801. June 11.			Gordon, Lieut.-General Sir James Willoughby, Bart. K.C.B. G.C.H. *Near the Royal Hospital, Chelsea.*
1830. Dec. 9.			Gordon, Henry Percy, Esq., M.A. *Near the Royal Hospital, Chelsea.*
1821. Feb. 8.			Gordon, Thomas, Esq. *Zante, Ionian Islands.*
1820. Apr. 27.			Goulburn, Right Hon. Henry, D.C.L. *Montagu-place, Portman-square.*
1843. Jan. 19.			Gould, John, Esq., F.L.S. 20 *Broad-street, Golden-square.*
1831. Dec. 22.			Graham, Right Hon. Sir James R. G., Bart. 31 *Hill-street; and Netherby, Cumberland.*
1836. Dec. 25.	R.P.		Graham, Thomas, Esq., M.A. Professor of Chemistry, University College, London, F.G.S. Hon. Memb. R.S.E. National Inst. Washington, U.S. et Acad. Reg. Sc. Berolin. et Monach. Corresp. 9 *Torrington-square.*
1846. Jan. 22.		†	Grainger, Richard Dugard, Esq., F.R.C.S. F.M.C.S. *Anerly, Norwood.*
1840. May 21.		†	Grant, Thomas Tassel, Esq. *Royal Clarence Victualling-yard, Portsmouth.*
1836. Feb. 4.			Grant, Robert Edmond, M.D. F.R.S.E. F.L.S. Professor of Comparative Anatomy and Zoology in University College. 10 *Grafton-place, Euston-square.*
1817. Nov. 20.	P.		Granville, Augustus Bozzi, M.D. F.G.S. M.R.A.S. Acadd. Reg. Sc. Brux., Acadd. Luc. et Pat.: Socc. Geogr. Flor., Ital., Vienn., Sc. Nat. Neap., Athen. Ven., Philom. Paris., Socius.—Acad. Imp. Sc. Petrop. et Reg. Taurin. Corresp. 109 *Piccadilly; and Rosemont, Great Missenden, Buckinghamshire.*
1832. Feb. 2.			Gravatt, William, Esq. 34 *Parliament-street.*
1839. Apr. 18.	P.		Graves, John Thomas, Esq., M.A. *Poor-Law Commission Office, Somerset-house.*
1832. Feb. 2.	P.		Gray, John Edward, Esq., F.G.S. F.R.G.S. Soc. Imp. Hist. Nat. Mosc. Acadd. Lync. Romæ, Sc. Nat. Philad. et Hist. Nat. Boston., Socius. *British Museum.*
1825. Feb. 24.			Green, Joseph Henry, Esq., Professor of Anatomy to the Royal Academy, F.G.S. *Barnet.*

Date of Election.			
1807. Mar. 5.			Greenough, George Bellas, Esq., F.L.S. F.G.S. M.R.A.S. *Grove-house, Regent's-park.*
1833. Feb. 7.			Greig, Woronzow, Esq., M.A. 14 *Lower Belgrave-street, Eaton-square.*
1830. June 10.			Gresswell, Rev. Richard, M.A. *Worcester College, Oxford.*
1841. Apr. 29.		†	Grey, Thomas Philip, Earl de. 4 *St. James's-square; and West-park, Silsoe, Bedfordshire.*
1834. Apr. 10.		†	Griffith, Edward, Esq., F.S.A. 6 *Nottingham-terrace, Marylebone.*
1806. May 1.	P.		Griffiths, John, Esq.
1840. Nov. 26.	P.		Grove, William Robert, Esq., M.A. Ph. D. Acadd. Reg. Taurin. et Soc. Phil. Basil. Socius Honor. 27 *Upper Gloucester-place, Dorset-square; and* 4 *Hare-court, Temple.*
1830. Apr. 22.			Grover, Capt. John, F.R.A.S. *Army and Navy Club.*
1839. June 20.			Guest, Edwin, Esq. 4 *King's-bench-walk, Temple.*
1830. June 10.			Guest, Sir Josiah John, Bart. F.G.S. 8 *Spring-gardens; and Dowlais Ironworks, Glamorganshire.*
1839. Mar. 7.			Gulliver, George, Esq. *Regent's-park Barracks.*
1818. Jan. 15.			Gurney, Hudson, Esq., V.P.S.A. M.R.S.L. 9 *St. James's-square; and Keswick-hall, near Norwich.*
1827. May 24.			Guthrie, George James, Esq. 4 *Berkeley-street, Piccadilly.*
1844. Apr. 18.		†	Haddington, Right Hon. Thomas, Earl of. *Tyningham-castle, Dunbar.*
1801. May 7.			Hailstone, Rev. John, M.A. F.L.S. F.G.S. *Trumpington, Cambridgeshire.*
1820. Apr. 27.		*	Hall, Sir John, Bart. F.R.S.E. F.G.S. 63 *Lowndes-square; and Dunglass, Dunbar, Haddingtonshire.*
1832. April 5.	P.		Hall, Marshall, M.D. F.R.S.E. Coll. Reg. Med. Socius. 14 *Manchester-square.*
1827. Nov. 22.			Hall, Thomas Henry, Esq., M.A. 49 *Tavistock-square.*
1821. Mar. 8.			Hallam, Henry, Esq., M.A. Trust. Brit. Mus. V.P.S.A. F.G.S. F.R.A.S. M.R.S.L. Instit. Reg. Sc. Paris. Socius. 24 *Wilton-crescent, Knightsbridge.*
1839. May 30.		†	Halliwell, James Orchard, Esq., Hon. M.R.I.A. F.S.A.L. & E. F.R.A.S. Hon. M.R.S.L. Socc. Reg. Antiq. Franc., Reg. Antiq. Septen. Hafn., Ethnol. Paris., Reg. Geogr. Paris., Asiatic. Paris., Corresp. *Avenue-lodge, Brixton-hill.*
1835. Feb. 5.		†	Hamett, Sir John, Knt. M.D. Deputy Medical Inspector of Hospitals and Fleets.
1808. Jan. 14.			Hamilton and Brandon, Alexander, Duke of, F.S.A. 12 *Portman-square; and Hamilton-palace, Lanarkshire.*
1828. Jan. 17.			Hamilton, Rev. H. Parr, M.A. F.G.S. F.R.A.S. *Wath Rectory, near Ripon.*
1813. April 8.			Hamilton, William Richard, Esq., V.P.S.A. For. Sec. R.S.L. Acad. Reg. Sc. Berolin. Socius Honor. 12 *Bolton-row, May-fair.*
1838. Jan. 18.		†	Hansler, Sir John Jacob, Knt. F.S.A. 8 *Westbourne-street, Hyde-park-gardens.*
1824. Apr. 29.			Harcourt, Rev. W. Venables Vernon, M.A. Hon. M.R.I.A. F.G.S. *Weldrake, near York.*
1838. April 5.		†	Hardwick, John, Esq., D.C.L. 5 *K, Albany, Piccadilly.*
1831. Dec. 8.			Hardwick, Philip, Esq., R.A. F.S.A. 60 *Russell-square.*
1839. Jan. 17.		†	Hardy, Peter, Esq. 37 *Old Jewry; and* 10 *Victoria-square, Pimlico.*
1823. May 29.			Harford, John Scandret, Esq., D.C.L.
1844. Apr. 18.	P.	†	Hargreave, Charles James, Esq., B.L. Professor of Jurisprudence, University College, London. 69 *Chancery-lane.*
1835. Feb. 5.		†	Harris, John Greathed, Esq., M.A. 25 *Chester-street.*

Date of Election.			
1831. June 2.	C.P.		Harris, William Snow, Esq. *Windsor Villas, Plymouth.*
1845. May 8.		†	Harrison, Thomas Charles, Esq. 31 *York-terrace, Regent's-park.*
1825. Feb. 17.			Harvey, Henry, Esq., F.R.A.S. 59 *Regency-square, Brighton.*
1835. April 2.		†	Harvey, Major-General Sir Robert John, C.B. K.T.S. K.S.B. F.S.A. *United Service Club; and Mousehold-house, near Norwich.*
1827. May 24.	P.	†	Harwood, John, M.D. F.L.S. *St. Leonard's, Hastings.*
1812. Jan. 9.			Hasted, Rev. Henry, M.A. F.L.S. *Bury, Suffolk.*
1797. Mar. 9.	C.P.		Hatchett, Charles, Esq., F.R.S.E. F.S.A. F.L.S. Instit. Reg. Sc. Paris. Corresp.—Acad. Reg. Sc. Monach., et Soc. Œcon. Petrop., Socius. *Belle-Vue-house, Chelsea; and Bollington, Lincolnshire.*
1821. Nov. 15.			Haughton, Sir Graves Chamney, K.H. M.A. Hon. M.R.I.A. M.R.A.S., Instit. Reg. Sc. Paris. Socius, Acad. Reg. Berolin. Corresp. 14 *Grafton-street, Bond-street.*
1834. Dec. 18.			Hawkins, Bissett, M.D. Coll. Reg. Med. Socius. 30 *Golden-square.*
1821. May 24.		*	Hawkins, Edward, Esq., F.S.A. F.L.S. *British Museum.*
1791. May 5.			Hawkins, John, Esq. *Quay-house, Devonshire.*
1830. June 10.			Hawkins, John Heywood, Esq., M.A. F.G.S. 16 *Suffolk-street; and Bignor-park, Petworth, Sussex.*
1835. Nov. 19.		†	Hawkins, Rev. William B. L., M.A. 23 *Great Marlborough-street.*
1814. Mar. 3.			Hay, Robert William, Esq., F.S.A.
1818. May 28.		*	Heath, George Crauford, Esq. *Cambridge.*
1843. Feb. 2.		†	Heath, John Benjamin, Esq., F.S.A. 66 *Russell-square.*
1846. April 23.			Henry, Thomas Hetherington, Esq. *Brick-lane, Spitalfields.*
1834. Apr. 10.			Henry, William Charles, M.D. *Haffield, near Ledbury, Herefordshire.*
1840. Feb. 27.		†	Henwood, William Jory, Esq. 4 *Clarence-street, Penzance.*
1813. May 27.	C.R. P.		Herschel, Sir John Frederick William, Bart. D.C.L. M.A. Trust. Brit. Mus. F.R.S.E. Hon. M.R.I.A. F.G.S. M.C.P.S. Instit. Reg. Sc. Paris. Corresp.—Acadd. Imp. Sc. Petrop., Reg. Berol., Taurin. Neap. et Brux.: Socc. Reg. Gotting., Hafn. et Harl.: Acadd. Lync. Romæ, Pat., Bonon., Panorm., Gioen. Catan. et Divion. ex intim., Socc. Philom. Paris., Ital. Mut., Helvet., Socius. *Collingwood, near Hawkhurst, Kent.*
1843. April 6.			Heygate, James, M.D. *College-house, Derby.*
1843. Jan. 19.			Heywood, Sir Benjamin, Bart. 9 *Hyde-park-gardens; and Claremont, Manchester.*
1839. Feb. 7.			Heywood, James, Esq., F.S.A. *Athenæum Club; and Acresfield, Manchester.*
1820. Mar. 23.			Higman, Rev. John Philip, M.A. F.G.S. F.R.A.S. *Rectory, Fakenham, Norfolk.*
1839. Jan. 10.		†	Hilton, John, Esq. 10 *New Broad-street.*
1809. Dec. 21.			Hoare, Charles, Esq., F.S.A. 37 *Fleet-street.*
1814. May 19.			Hobhouse, Right Hon. Sir John Cam, Bart. M.A. 42 *Berkeley-square.*
1811. June 27.			Hoblyn, Thomas, Esq., F.L.S.
1841. Feb. 18.	R.P.		Hodgkinson, Eaton, Esq., F.G.S. 14 *Salford-crescent, Manchester.*
1831. Apr. 14.			Hodgson, Joseph, Esq. *Birmingham.*
1839. June 20.		†	Hogg, John, Esq., M.A. F.L.S. F.C.P.S. M.R.S.L. 12 *King's-bench-walk, Inner Temple; and Norton-house, Stockton-upon-Tees.*
1837. Jan. 19.			Holland, Charles, M.D. 16 *Queen-street, May-fair.*
1815. Jan. 19.	P.		Holland, Henry, M.D. F.G.S. Coll. Reg. Med. Socius. 25 *Brook-street.*
1826. Feb. 2.			Holman, James, Esq., Lieut. R.N. F.L.S. *Windsor.*

Date of Election.			
1825. Apr. 21.	P.		Home, Sir Everard, Bart. Capt. R.N. F.S.A. H.M. Ship North Star.
1843. Dec. 7.			Hood, Charles, Esq., F.R.A.S. *Earl-street, Blackfriars; and Camberwell.*
1812. Jan. 9.			Hooker, Sir William Jackson, K.H. LL.D. Hon. M.R.I.A. F.S.A. F.L.S. F.G.S. Acad. Cæs. Nat. Cur. Socius. *Kew.*
1834. June 5.		†	Hope, Rev. Frederick William, M.A. F.L.S. 56 *Upper Seymour-street.*
1837. June 1.	P.	†	Hopkins, William, Esq., M.A. *Fitzwilliam-street, Cambridge.*
1841. May 20.			Hoppus, Rev. John, LL.D. Ph.D. Professor of Philosophy and Logic, University College, London. 39 *Camden-street, Camden-town.*
1834. Feb. 6.			Horne, James, Esq. *Clapham-common.*
1813. Nov. 11.	P.		Horner, Leonard, Esq., F.R.S.E.—Vice-President.—President of the Geological Society. Soc. Sc. Harlem. Socius. 2 *Bedford-place.*
1828. Jan. 10.		†	Horsfield, Thomas, M.D. F.L.S. F.G.S. M.R.A.S. Acad. Cæs. Nat. Cur. Socius. 43 *Markham-square, King's-road, Chelsea.*
1843. May 25.	P.		Hoskins, Samuel Elliott, M.D. *Guernsey.*
1821. Mar. 8.	P.		Howard, Luke, Esq. *Bruce-grove, Tottenham; and Ackworth-villa, Pomfret.*
1834. Apr. 10.			Hudson, Robert, Esq., F.G.S. *Clapham-common.*
1818. Jan. 8.			Hume, Joseph, Esq. 6 *Bryanston-square.*
1819. Nov. 11.			Hunt, Rev. George, M.A. F.S.A. *Egg Buckland, near Plymouth.*
1837. April 6.		†	Hunter, Robert, Esq., F.G.S. F.S.A. *Highgate.*
1819. Nov. 18.			Hustler, Rev. James Devereux, B.D. *Euston-rectory, near Thetford, Norfolk.*
1829. Mar. 19.			Hutchinson, Lieut.-Colonel George, E.I.C.S. Be. Engineers. 18 *Gloucester-place, Portman-square.*
1840. June 4.		†	Hutton, William, Esq. *Newcastle-upon-Tyne.*
1844. Feb. 29.		†	Hyett, William Henry, Esq. *Painswick-house, Painswick.*
1838. May 31.			Hymers, Rev. John, D.D. *St. John's College, Cambridge.*
1813. Mar. 4.			Inglis, Sir Robert Harry, Bart. LL.D. Trust. Brit. Mus. F.S.A. F.R.A.S. 7 *Bedford-square.*
1807. Apr. 23.			Jacob, William, Esq., Instit. Sc. Paris. Corresp. 31 *Cadogan-place, Sloane-street.*
1845. Apr. 3.		†	Jackson, Colonel Julian, Secretary to the R.G.S. *Royal Geographical Society; and* 52 *Coleshill-street, Pimlico.*
1826. May 25.			Jameson, Robert, Esq., Regius Professor of Natural History, Edinburgh. F.R.S.E. Hon. M.R.I.A. F.L.S. F.G.S. Acad. Reg. Sc. Neap.: Socc. Reg. Sc. Dan., Imp. Hist. Nat. Mosc., Hist. Nat. Veter. et Paris., Philom. Paris., Amer. Philad., Phil. et Hist. Nov.-Ebor., Socius.—Acad. Reg. Sc. Berol. Corresp. *Edinburgh.*
1841. Jan. 7.		†	Jeffereys, Julius, Esq. 25 *A, Norfolk-crescent, Hyde-park.*
1840. April 2.		†	Jeffreys, John Gwyn, Esq., F.L.S. *Norton, near Swansea.*
1841. Feb. 18.		†	Jenkins, Sir Richard, G.C.B. *India House; and Bickton-hall, Shrewsbury.*
1821. Mar. 1.			Jennings, Rev. Philip, D.D. *Hampstead-green.*
1838. Mar. 15.		†	Jervis, Thomas Best, Esq., Major E.I.C.E. F.L.S. F.G.S. F.R.A.S.
1842. May 5.		†	Jesse, John, Esq., F.R.A.S. F.L.S. *Frodsham, Cheshire.*
1842. Mar. 10.		†	Johnson, Cuthbert William, Esq. 14 *Gray's-inn-square.*
1836. Mar. 10.	P.	†	Johnson, Edward John, Esq. Captain R.N. 13 *Clement's-inn.*
1838. Jan. 18.			Johnson, Rev. George Henry Sacheverell, M.A. Professor of Moral Philosophy in the University of Oxford. *Oxford.*

Date of Election.		
1846. April 30.		† Johnson, Percival Norton, Esq., F.G.S. 38 *Mecklenburgh-square; and Henton-house, Tavistock.*
1810. Nov. 22.	P.	Johnston, Right Hon. Sir Alexander, Knt. F.S.A. V.P.R.A.S. 19 *Great Cumberland-place; and York-house, Twickenham.*
1845. June 5.		† Johnston, Alexander Robert, Esq.
1837. June 15.		Johnston, James F. W., Esq., M.A. F.R.S. Ed. Professor of Chemistry and Mineralogy in the University of Durham. *Durham.*
1846. April 30.	P.	Jones, Henry Bence, Esq., M.A. Coll. Reg. Med. Socius. 30 *Lower Grosvenor-street, Grosvenor-square.*
1835. June 4.	P.	† Jones, Thomas, Esq., F.R.A.S. 62 *Charing-cross; and West-square.*
1844. Mar. 21.		† Jones, Thomas Rymer, Esq., Professor of Comparative Anatomy, King's College. 120 *Camden-road Villas.*
1840. Apr. 30.	P.	† Jones, Thomas Wharton, Esq. 35 *George-street, Hanover-square.*
1840. Nov. 19.	P.	Kater, Edward, Esq., F.G.S. M.R.I.A. *Mexborough, Yorkshire; and Athenæum Club.*
1846. Feb. 26.		† Kay, Joseph Henry, Esq., Lieut. R.N.
1838. Dec. 6.		† Kelland, Rev. Philip, M.A. F.R.S.E. M.C.P.S. Professor of Mathematics in the University of Edinburgh. *Edinburgh.*
1844. Feb. 29.		† Kerigan, Thomas, Esq., R.N. 9 *St. Paul's-square, Southsea, Portsmouth.*
1841. Mar. 18.		† Kerrison, Robert Masters, M.D. 35 *Upper Brook-street.*
1822. Mar. 28.	P.	Kidd, John, M.D. Regius Professor of Medicine, and Aldrich's Professor of Anatomy, Oxford, F.L.S. F.G.S. Coll. Reg. Med. Socius. *Oxford.*
1834. Dec. 18.	C.P.	Kiernan, Francis, Esq. 30 *Manchester-street, Manchester-square.*
1824. Feb. 26.		King, Philip Parker, Esq. Captain R.N. F.L.S. *Dunheved, New South Wales.*
1818. Mar. 5.		Kirby, Rev. William, M.A. F.L.S. F.G.S. Acad. Cæs. Nat. Cur., et Soc. Nat. Scrutat. Berol. Socius. *Barham, near Ipswich.*
1830. Mar. 4.		Knowles, Sir Francis Charles, Bart. M.A.
1810. Jan. 18.	P.	* Konig, Charles, Esq., K.H. Hon. M.R.I.A. F.L.S. Acad. Reg. Sc. Monach. Socius.—Acad. Imp. Sc. Petrop., et Soc. Reg. Gotting. Corresp.—Soc. Imp. Hist. Nat. Mosc. Socius.—Acad. Panorm., et Soc. Veterav., Sodalis. *British Museum.*
1843. Nov. 23.		Laing, Rev. David. 62 *Mornington-road, Regent's-park.*
1846. Dec. 19.		† Lankester, Edwin, M.D. F.L.S. *Old Burlington-street.*
1811. April 4.		Lansdowne, Henry, Marquis of, D.C.L. Trust. Brit. Mus. M.R.S.L. 52 *Berkeley-square; and Bowood-park, Wiltshire.*
1844. May 16.		Larcom, Thomas Aiskew, Capt. R.E.
1813. Nov. 11.		Lawrence, William, Esq., President of the Royal College of Surgeons of England. 18 *Whitehall-place.*
1840. May 21.		† Lawson, Henry, Esq, 7 *Lansdowne-crescent, Bath.*
1815. Apr. 13.		Leake, Lieut.-Colonel William Martin, M.R.S.L. Acad. Reg. Sc. Berol. Socius Honor. Instit. Reg. Paris. Corresp. 50 *Queen-Anne-street.*
1843. May 11.		† Le Couteur, Colonel John. *Belle Vue, Jersey.*
1831. Feb. 24.		Lee, John, LL.D. F.R.A.S. 5 *College, Doctors'-commons; and Hartwell-house, near Aylesbury, Buckinghamshire.*
1830. Mar. 25.	P.	Lee, Robert, M.D. Coll. Reg. Med. Socius. 4 *Saville-row.*
1820. Nov. 16.		Lefevre, John George Shaw, Esq., M.A. Vice-Chancellor of the University of London. *Board of Trade, Whitehall.*

Date of Election.			
1817. June 12.			Legh, Thomas, Esq., D.C.L. *Lyme-park, Cheshire.*
1822. May 23.			Lemon, Sir Charles, Bart. 46 *Charles-street, Berkeley-square; and Carclew, near Falmouth, Cornwall.*
1836. May 5.		†	Lewis, Thomas Locke, Esq. Capt. R.E. F.G.S. *Ibsley-cottage, Exeter.*
1846. June 18.		†	Liddell, John, M.D. *Greenwich Hospital.*
1811. Mar. 7.			Lincoln, John Kaye, Lord Bishop of. *Cambridge; and Buckden-palace, Huntingdonshire.*
1828. Jan. 17.		†	Lindley, John, Phil. D. F.L.S. Acad. Reg. Berol. Corresp.; Acad. Cæs. Nat. Cur., Socc. Physiogr. Lund., Linn. Holm., Socius.—Soc. Batav. Sc., Lyc. Nat. Hist. Nov.-Ebor., Socius Honor.—Prof. Bot. Univ. Coll. Lond. 21 *Regent-street.*
1832. Feb. 2.	P.		Lister, Joseph Jackson, Esq. *Upton, Essex.*
1841. May 13.		†	Liston, Robert, Esq. 5 *Clifford-street, New Bond-street.*
1836. Feb. 4.			Llewelyn, John Dillwyn, Esq., F.L.S. *Penllegare, Glamorgan.*
1818. Mar. 12.			Lloyd, Edward, Esq. Captain R.N. *United Service-club.*
1830. Mar. 11.	P.	†	Lloyd, Lieut.-Col. John Augustus, Surveyor-General. *Port Louis, Mauritius.*
1834. Apr. 10.			Lloyd, Rev. William Forster, M.A. *Missenden, Bucks.*
1836. Jan. 21.			Lloyd, Rev. Humphrey, D.D. M.R.I.A. *Dublin.*
1838. Feb. 22.		†	Locke, Joseph, Esq. 6 *Chester-terrace, Regent's-park.*
1811. Dec. 5.			Locker, Edward Hawke, Esq., F.S.A. *Richmond.*
1841. Nov. 25.		†	Lovelace, William King, Earl of. 10 *St. James's-square; Ockham-park, Ripley, Surrey; and Ashley-combe, Postock, Somerset.*
1834. Dec. 18.		†	Lowe, George, Esq. 39 *Finsbury-circus.*
1810. July 5.			Lowther, William Viscount, F.S.A. 14 *Carlton-terrace; and Lowther-castle, near Penrith.*
1829. Jan. 15.	R.P.		Lubbock, Sir John William, Bart. M.A. F.L.S. F.R.A.S. M.R.A.S. 23 *St. James's-place; and High Elms, Farnborough, Kent.*
1826. Feb. 2.	R.P.		Lyell, Charles, Jun. Esq., M.A. F.L.S. F.G.S. 11 *Harley-street, Cavendish-square.*
1826. Apr. 13.			Lyndhurst, John Singleton, Lord, D.C.L. 25 *George-street, Hanover-square.*
1840. Apr. 30.		†	Lyttleton, George William, Lord. 39 *Grosvenor-place; and Hagley-park, near Stourbridge, Worcestershire.*
1843. Feb. 2.	C.		MacCullagh, James, Esq., D.C.L. Professor of Natural and Experimental Philosophy in the University of Dublin. *Trinity-college, Dublin.*
1816. Mar. 14.			MacGrigor, Sir James, Bart., F.R.S.E. Coll. Reg. Med. Socius. *Harley-street.*
1815. Apr. 13.			Mackenzie, Sir George Steuart, Bart. F.R.S.E. *Coul, Ross-shire.*
1817. May 15.			Mackie, Rev. John William, M.A. 27 *Upper Baker-street.*
1827. June 14.			Mackinnon, William Alexander, Esq., M.A. F.S.A. F.G.S. 4 *Hyde-park-place; and Newton-park, Lymington, Hants.*
1831. Dec. 8.	P.		Maclear, Thomas, Esq., F.R.A.S. Astronomer Royal at the Cape of Good Hope.
1809. Jan. 19.			MacLeay, Alexander, Esq., F.L.S. Acad. Reg. Sc. Holm. Socius, et Acad. Reg. Sc. Taurin. Corresp. *Sydney, New South Wales.*
1839. May 30.		†	Mackmurdo, Gilbert Wakefield, Esq. *St. Thomas's Hospital; and* 7 *New Broad-street.*
1838. April 5.		†	Macneill, Sir John, F.R.A.S. M.R.I.A. 9 *Whitehall-place.*
1832. Feb. 2.		†	Madden, Sir Frederick, K.H. Hon. M.R.I.A. F.S.A. Soc. Reg. Antiq. Septen. Hafn. Socius. *British Museum.*
1817. June 12.			Maddy, Rev. John, D.D. F.S.A. F.R.A.S. *Somertown, Bury St. Edmunds.*

Date of Election.		
1819. June 24.		Magrath, Sir George, K.H. M.D. M.R.I.A. F.L.S. F.G.S. *Plymouth.*
1827. Mar. 22.		† Mahon, Philip H., Viscount, D.C.L. P.S.A. 41 *Grosvenor-place; and Chevening-place, Kent.*
1839. Apr. 18.		† Maitland, Rev. Samuel Roffy. *Lambeth-palace.*
1829. May 28.		Maitland, Ebenezer Fuller, Esq., F.S.A. *Henley-on-Thames, Oxfordshire.*
1821. June 28.		* Majendie, Ashurst, Esq., F.G.S. *Hedingham-castle, Castle Hedingham, Essex.*
1831. May 12.		Manby, George William, Capt. R.N. *Yarmouth.*
1825. Jan. 20.		Mangles, James, Esq., Capt. R.N. 66 *Cambridge-terrace, Edgware-road.*
1825. Nov. 24.	P.	Mantell, Gideon Algernon, Esq., LL.D. F.L.S. F.G.S. Coll. Reg. Med. Socius, Soc. Philom. Paris. Corresp. Acadd. Philad. et Connect., Socius Honor. 19 *Chester-square, Pimlico.*
1836. Jan. 28.		Marcet, Francis, Esq. *Geneva.*
1816. Mar. 28.		Markland, James Heywood, Esq., F.S.A. *Bath.*
1819. May 13.		Marryatt, Frederick, Esq., Capt. R.N. *Wimbledon.*
1845. Feb. 13.		Martin, James Ranald, Esq., F.R.M. & C.S. M.R.A.S. 71 *A, Grosvenor-street.*
1823. Nov. 27.		Maskelyne, Anthony Mervin Story, Esq., M.A. *Basset-Down-house, Swindon.*
1846. Feb. 19.		† Matheson, James, Esq. 13 *Cleveland-row.*
1832. Feb. 2.		Mauley, Lord de. 24 *George-street, Hanover-square; and Canford-house, near Wimborne, Dorset.*
1829. Feb. 26.		Maxwell, John, Esq. *Pollock, Renfrewshire.*
1827. Mar. 1.		† Mayo, Rev. Charles, B.D. F.S.A. *Colesgrove, near Cheshunt, Hertfordshire.*
1828. Apr. 17.		† Mayo, Herbert, Esq.
1835. June 4.		† Mayo, Thomas, M.D. Coll. Reg. Med. Socius. 56 *Wimpole-street.*
1841. Feb. 25.		† Melbourne, William, Viscount. 39 *South-street, Grosvenor-square; and Brocket-hall, Herts.*
1841. Jan. 14.		† Melvill, James Cosmo, Esq. *East India House.*
1817. May 15.		Melville, Robert Viscount, K.T. F.R.A.S. 3 *Somerset-place; and Melville-castle, Edinburgh.*
1838. May 3.		† Merewether, Very Rev. John, D.D. Dean of Hereford, F.S.A. *Hereford.*
1843. Mar. 9.		† Miers, John, Esq., F.L.S. *Temple Lodge, Hammersmith.*
1843. Mar. 30.		† Miller, Joseph, Esq. *Monastery-cottage, East-India-road.*
1827. May 24.	P.	Miller, Lieut.-Colonel George, C.B.
1845. Feb. 6.	P.	Miller, William Allen, M.D. Professor of Chemistry, King's College, London. *King's College.*
1838. Feb. 8.		Miller, William Hallows, Esq. M.A. Professor of Mineralogy. *Cambridge.*
1836. Mar. 3.		Minto, Gilbert Elliot Murray Kynynmound, Earl of, F.R.A.S. *Minto-castle, Roxburghshire.*
1835. Nov. 26.		Molesworth, Sir William, Bart. 1 *Lowndes-square; and Pencarrow, Cornwall.*
1841. Apr. 29.		† Monteagle, Thomas, Lord. 37 *Lower Brook-street; and Exchequer-office, Whitehall.*
1845. Feb. 13.		† Monteith, Major-General William. *Wilmington, Dartford.*
1836. June 16.		Montefiore, Sir Moses, Knt. 7 *Grosvenor-gate, Park-lane; and East Cliff-lodge, Ramsgate.*
1806. May 6.		Moore, Major Edward, F.S.A. M.R.A.S. *Bealings, near Woodbridge, Suffolk.*
1835. April 2.		† Moore, George, Esq., F.S.A. F.L.S. 64 *Lincoln's-inn-fields.*

Date of Election.			
1846. Feb. 26.		†	Moore, Major John Arthur, F.S.A. 4 *Upper Harley-street; and Boyle-cottage, Thames Ditton.*
1827. Feb. 8.			Moreau, César, Esq., Acadd. Reg. Divion., Burd., et Masil., Socius. *Paris.*
1835. April 2.		†	Morgan, Arthur, Esq. 26 *New Bridge-street, Blackfriars.*
1816. May 30.			Morgan, Charles, Esq., F.S.A. 70 *Pall-mall; and Tredegar-house, near Newport, Monmouthshire.*
1832. Feb. 2.		†	Morgan, Octavius S., Esq. M.A. F.S.A. 70 *Pall-mall; and Tredegar-park, Monmouthshire.*
1819. Feb. 4.			Morier, James, Esq. 22 *Charles-street, Berkeley-square.*
1831. Mar. 10.			Morris, John Carnac, Esq.
1842. Mar. 3.		†	Morison, Major-General William, C.B. F.R.S.E. *Oriental-club, or* 16 *Saville-row.*
1839. Feb. 7.	P.	†	Moseley, Rev. Henry, M.A. *Wandsworth.*
1830. Feb. 18.			Moss, Joseph William, M.B. *Dudley.*
1822. Dec. 5.			Mudge, Rich. Zachariah, Esq., Lieut.-Col. R.E. *Beechwood, Plympton, Devon.*
1826. April 6.			Murchison, Sir Roderick Impey, G.C.St.S. M.A. President Brit. Assoc. Adv. of Science, Hon. Mem. R.S.Ed. R.I. Ac., and Cam. Phil. Soc. V.P.G.S. and R. Geogr. Soc., F.L.S. Acad. Imp. Sc. Petrop. Acad. Amer. Art. et Sc. Bost. Socius, Inst. Reg. Sc. Paris. et Acad. Reg. Taurin. Corresp., et Soc. Imp. Sc. Nat. Hist. Mosq. Socius., &c. &c. 16 *Belgrave-square.*
1826. Mar. 16.			Mylne, William Chadwell, Esq., F.R.A.S. *New-River-head.*
1820. May 18.		*	Napier, Henry, Esq., Capt. R.N. *Cadogan-place.*
1817. June 12.			Napier, Macvey, Esq., F.R.S.E. *Edinburgh.*
1840. June 18.		†	Narrien, John, Esq., F.R.A.S., Professor of Mathematics in the Royal Military College, Sandhurst. *Sandhurst.*
1814. May 5.			Neave, Sir Thomas, Bart. F.S.A. 6 *Albemarle-street; and Dagenham-park, Rumford, Essex.*
1846. Jan. 15.			Neilson, James B., Esq. *Glasgow.*
1842. Jan. 6.	P.		Newbold, Thomas John, Esq., Lieut. E.I.C.S. *Madras.*
1846. Mar. 26.	R.P.	†	Newport, George, Esq., F.R.C.S. Soc. Philom. Paris. Corresp. *Upper Southwick-street.*
1833. Feb. 7.		†	Nolan, Rev. Frederick, LL.D. M.R.S.L. *Prittlewell, Essex.*
1842. Dec. 15.			Norfolk, The Most Noble Howard, Duke of. 1 *Hyde-park-place.*
1830. May 27.			Northampton, Spencer Joshua Alwyne, Marquis of.—PRESIDENT.—Trust. Brit. Mus. F.S.A. Hon. M.R.I.A. F.L.S. F.G.S. 145 *Piccadilly; and Castle Ashby, Northampton.*
1823. May 1.			Northumberland, Hugh, Duke of, K.G. M.A. Trust. Brit. Mus. F.S.A. F.L.S. F.G.S. *Northumberland-house, Strand.*
1840. June 4.		†	Norwich, Edward Stanley, Lord Bishop of, President of the Linnean Society. 38 *Lower Brook-street; and Palace, Norwich.*
1826. Feb. 2.		†	Ogle, James Adey, M.D. F.R.A.S. Coll. Reg. Med. Socius. Lord Lichfield's, and Aldrich's Professor of Medicine, Oxford.
1786. Nov. 16.			Oldershaw, Venerable John, B.D. Archdeacon of Norfolk. *Harlestone, Norfolk.*
1835. June 4.			Oliveira, Benjamin, Esq., F.S.A. 8 *Upper Hyde-park-street.*
1824. Mar. 4.			Orford, Horatio, Earl of. *White's Club; and Wolterton-park, Norfolk.*
1819. Feb. 25.			Ormerod, George, Esq., D.C.L. F.S.A. F.G.S. *Sudbury-park, Gloucestershire.*

Date of Election.		
1843. Mar.16.		† O'Shaughnessy, William Brooke, Esq., M.D. *Calcutta.*
1838. May 3.	P.	Outram, Benjamin Fonseca, M.D. F.R.G.S. 1 *Hanover-square.*
1834. Dec. 18.	R.P.	Owen, Richard, Esq., M.D. F.L.S. V.P.G.S. Instit. Sc. Paris. Corresp. Fellow and Hunterian Professor of Anatomy and Physiology in the Royal College of Surgeons of England. *Royal College of Surgeons, Lincoln's-inn-fields.*
1845. Dec. 18.		† Oxford, Samuel Wilberforce, Lord Bishop of. 61 *Eaton-place.*
1821. Nov. 15.	P.	Palgrave, Sir Francis, K.H. Deputy Keeper of Her Majesty's Records. *Rolls'-yard, Chancery-lane; and Hampstead-green.*
1821. June 21.		* Paris, John Ayrton, M.D. President of the Royal College of Physicians.—VICE-PRESIDENT. 28 *Dover-street.*
1824. Mar. 4.	P.	Parish, Sir Woodbine, K.C.H. F.S.A. F.G.S. *Naples.*
1815. June 1.		Parker, Thomas Lister, Esq., F.S.A. 34 *Mount-street.*
1840. Feb. 6.		† Parkinson, John, Esq., F.L.S. 80 *Cambridge-terrace, Hyde-park.*
1812. Feb. 20.	P.	Parry, Charles Henry, M.D. *Bath.*
1821. Feb. 15.	P.	Parry, Sir William Edward, Knt. D.C.L. Capt. R.N. Hon. M.R.I.A. F.R.A.S. Acad. Imp. Sc. Petrop. Socius, Inst. Reg. Sc. Paris. *Superintendent of Haslar Hospital, Gosport.*
1837. Feb. 23.		† Partridge, Richard, Esq. 17 *New-street, Spring-gardens.*
1816. Mar. 7.		Pasley, Major-General Charles William, R.E. C.B. F.R.A.S. F.G.S. 12 *Norfolk-crescent, Hyde-park.*
1818. Jan. 29.		Peacock, Very Rev. George, D.D. Dean of Ely, F.G.S. F.R.A.S. *Deanery, Ely.*
1833. Dec. 5.		Pearson, Sir Edwin, K.H. M.A. 5 *Gloucester-terrace, Regent's-park.*
1819. July 1.		Pearson, Rev. William, LL.D. F.R.A.S. *South Kilworth, near Welford, Northamptonshire.*
1826. Mar. 9.		Pearson, Sir William, Knt. M.D.
1832. Feb. 2.		Pechell, Sir Samuel John Brooke, Bart. Capt. R.N. 27 *Hill-street, Berkeley-square.*
1822. Dec. 5.		Peel, Right Hon. Sir Robert, Bart. D.C.L. Trust. Brit. Mus. F.S.A. *Whitehall-gardens; and Drayton-Manor, Fazeley, Staffordshire.*
1835. April 2.		† Pelly, Sir John Henry, Bart. *Trinity-house.*
1813. Feb. 11.		Pemberton, George, Esq. *Bainbridge Holme, Durham; and* 20 *Edgware-road.*
1827. May 24.		Pendarves, Edward William Wynne, Esq., M.A. F.G.S. 36 *Eaton-place, Belgrave-square; and Pendarves, Truro, Cornwall.*
1824. Nov. 18.		Penn, Richard, Esq. 6 *Whitehall.*
1808. Jan. 28.	P.	Pepys, William Hasledine, Esq., F.L.S. 22 *Poultry.*
1838. May 3.		† Pereira, Jonathan, M.D. F.L.S. 47 *Finsbury-square.*
1807. Dec. 10.		Petit, Louis Hayes, Esq., M.A. F.S.A. F.L.S. F.G.S. F.R.A.S. M.R.S.L. 9 *New-square, Lincoln's-inn.*
1817. Mar. 6.		Petre, William Francis Henry, Lord. 3 *Mansfield-street; and Thorndon-hall, near Brentwood, Essex.*
1827. Feb. 1.		† Pettigrew, Thomas Joseph, Esq., F.S.A. M.R.A.S. Univ. Gotting. Phil. Doct.—Acad. Reg. Divion. Socius. 8 *Saville-row.*
1826. Apr. 11.	P.	Philip, Alexander Philip Wilson, M.D. Coll. Reg. Med. Socius. F.R.S.E.
1840. Feb. 13.		† Phillimore, Joseph, LL.D. 15 *College, Doctors'-commons; and* 22 *Portman-street.*

Date of Election.			
1819. Jan. 29.			Phillipps, Sir Thomas, Bart. M.A. F.S.A. F.G.S. Hon. M.R.S.L. *Middle-hill, Worcestershire.*
1834. Dec. 18.			Phillips, Benjamin, Esq. 17 *Wimpole-street, Cavendish-square.*
1834. Apr. 10.		†	Phillips, John, Esq., Prof. F.G.S. *York.*
1822. Mar. 14.	P.	*	Phillips, Richard, Esq., F.R.S.E. 6 *Craig's-court, Charing-cross; and Camberwell-green.*
1791. Mar. 10.			Pocock, Sir George, Bart. *Bransgore-house, Ringwood, Hampshire.*
1829. April 9.			Pole, William, Esq. M.A. 66 *Brook-street.*
1829. April 9.			Pollock, Sir David, Knt., F.R.A.S. M.R.A.S. M.R.S.L. *Bombay.*
1816. Feb. 29.			Pollock, The Right Hon. Sir Frederick, Chief Baron of the Exchequer, K.H. M.A. F.S.A. F.G.S. *Queen-square-house, Guildford-street.*
1838. Jan. 18.		†	Porter, George Richardson, Esq., M.R.A.S. Instit. Reg. Sc. Paris. Corresp. *Board of Trade, Whitehall.*
1837. June 8.			Portlock, Joseph Ellison, Esq., Capt. R.E. F.G.S. *Cork.*
1824. May 13.	P.		Powell, Rev. Baden, M.A. F.R.A.S. Savilian Professor of Geometry, Oxford. *Oxford.*
1842. Jan. 27.		†	Pratt, Samuel Peace, Esq., F.L.S. F.G.S. 55 *Lincoln's-inn-fields; and Bath.*
1827. Feb. 8.			Prichard, James Cowles, M.D. Hon. M.R.I.A. Instit. Reg. Sc. Paris. Corresp. 1 *Woburn-place, Russell-square.*
1840. Feb. 6.		†	Pritchard, Rev. Charles, M.A. *Clapham.*
1819. Mar. 11.	C.P.	*	Prout, William, M.D. Coll. Reg. Med. Socius. 40 *Sackville-street.*
1818. April 9.			Prudhoe, Algernon, Lord, F.S.A. President of the Royal Institution of Great Britain. *Whitehall-gardens; and Stanwick-park, Darlington, Yorkshire.*
1830. May 27.			Pusey, Philip, Esq. 35 *Grosvenor-square; and Pusey-house, near Faringdon, Berks.*
1844. Feb. 29.		†	Quain, Richard, Esq. Professor of Anatomy, University College, London. 23 *Keppel-street.*
1814. Dec. 15.			Rashleigh, William, Esq., F.L.S. 3 *Cumberland-terrace, Regent's-park; and Menabilly-house, Foy, Cornwall.*
1837. Jan. 19.		†	Rastrick, John Urpath, Esq. 46 *Eaton-square.*
1838. Feb. 8.			Reade, Rev. Joseph Bancroft, M.A. *Stone Vicarage, Aylesbury.*
1843. Feb. 2.	P.		Rees, George Owen, M.D. F.G.S. Coll. Reg. Med. Socius. 59 *Guildford-street, Russell-square.*
1817. June 12.			Reeves, John, Esq., F.L.S. F.R.A.S. *Clapham.*
1834. Feb. 6.			Reeves, John Russell, Esq., F.L.S. *Clapham.*
1839. Feb. 21.		†	Reid, Lieut.-Colonel William, C.B. R.E. Governor of Jamaica.
1843. Feb. 23.		†	Rendel, James Meadows, Esq. 8 *Great George-street, Westminster.*
1822. Mar. 21.			Rennie, George, Esq.—VICE-PRESIDENT AND TREASURER.—Hon. M.R.I.A. 21 *Whitehall-place.*
1823. June 12.	P.		Rennie, Sir John, Knt. President of the Institution of Civil Engineers. 15 *Whitehall-place.*
1845. May 22.			Rennie, James, Esq. 6 *Whitehall-place.*
1825. Feb. 24.			Richardson, Sir John, Knt. M.D. F.L.S. Acad. Sc. Nat. Philad., Georg. Paris. Corresp.—Socc. Hist. Nat. Montreal, Lit. et Phil. Quebec, Hist. Nat. Boston, Socius Honor. *Haslar-hospital, Gosport.*

Date of Election.		
1840. April 2.		† Richmond, Charles Gordon Lennox, Duke of, K.G. President of the Royal Agricultural Society. 51 *Portland-place; and Goodwood, near Petworth, Sussex.*
1820. Mar. 23.		Ricketts, Charles Milner, Esq., F.G.S. *Lima.*
1842. Jan. 13.		Riddell, Charles James Buchanan, Esq., Capt. R.A. *Woolwich.*
1839. Apr. 25.	P.	Rigg, Robert, Esq. *Greenford, Middlesex.*
1828. Apr. 17.		Ripon, Frederick John, Earl of. 4 *St. James's-square.*
1836. Feb. 11.		Robertson, Archibald, M.D. *Northampton.*
1796. Nov. 17.		Rogers, Samuel, Esq., F.S.A. 22 *St. James's-place.*
1839. Dec. 5.		Rogers, John, jun. Esq. *Vine-lodge, near Sevenoaks, Kent.*
1815. Mar. 16.	P.	Roget, Peter Mark, M.D.—SECRETARY.—F.G.S. F.R.A.S. V.P.S.A. Coll. Reg. Med. et Acad. Reg. Scient. Taurin. Socius. 18 *Upper Bedford-place, Russell-square.*
1844. Feb. 1.		† Ronalds, Francis, Esq. *Chiswick.*
1831. June 9.		Ros, Hon. I. Frederick F. de, Capt. R.N. F.R.A.S. 116 *Piccadilly.*
1834. June 5.		Rose, Sir George, Knt. 4 *Hyde-park-gardens.*
1819. April 1.		Rosebery, Archibald John, Earl of, K.T. 139 *Piccadilly; and Dalmeney-park, Linlithgow.*
1822. June 13.		Ross, Captain Daniell. *India.*
1828. Dec. 11.	P.	Ross, Sir James Clark, Knt. Capt. R.N. D.C.L. F.L.S. F.R.A.S. Soc. Reg. Sc. Hafn. Socius. *Aston House, Aston Abbots, Aylesbury.*
1831. Dec. 8.	P.	Rosse, William, Earl of, F.R.A.S. *Birr-castle, King's-county, Ireland.*
1839. Dec. 12.		† Roupell, George Leith, M.D. 15 *Welbeck-street.*
1837. April 6.		† Royle, John Forbes, M.D. F.L.S. F.G.S. F.R.A.S. Professor of Materia Medica and Therapeutics, King's-college. 4 *Bulstrode-street, Manchester-square.*
1821. June 7.		Russell, Jesse Watts, D.C.L. F.S.A. F.L.S. F.G.S. *Ilam-hall, Staffordshire.*
1818. Apr. 16.	C.P.	Sabine, Lieut.-Colonel Edward, R.A.—FOREIGN SECRETARY.—F.R.A.S. Acadd. Imp. Sc. Petrop., Reg. Sc. Taur., Brux., Norv. Phil. et Œcon. Siles. Socius: Socc. Reg. Sc. Gotting., Soc.: Vaud., Mem. National Inst. Washington U.S. et Geogr. Paris., Corresp.—Mem. of Royal Batavian Soc. *Athenæum Club; and Woolwich.*
1832. Dec. 6.		Sandford, Edward Ayshford, Esq. *Nynehead, Somerset.*
1833. Apr. 18.		† Saunders, Rev. Augustus Page, D.D. *Charterhouse-school.*
1822. June 27.		Sawbridge, Henry Barne, Esq.
1824. June 17.	P.	Scoresby, Rev. William, D.D. F.R.S.E. Instit. Reg. Sc. Paris. Corresp. Vicar of Bradford, Yorkshire. *Bradford.*
1800. Jan. 16.		Scott, John Corse, Esq. *Edinburgh.*
1826. Dec. 7.		Scrope, George Poulett, Esq., F.G.S. 13 *Belgrave-square; and Castle Combe, Chippenham, Wiltshire.*
1824. Jan. 15.		† Scudamore, Sir Charles, Knt. M.D. 6 *Wimpole-street.*
1821. Feb. 1.		Sedgwick, Rev. Adam, M.A. Hon. M.R.I.A. F.G.S. F.R.A.S. Woodwardian Lecturer. *Cambridge.*
1831. Jan. 13.		Selkirk, Thomas James, Earl of. *St. Mary's Isle, Kirkcudbright.*
1841. June 17.		† Seymour, Edward James, M.D. Coll. Reg. Med. Socius. 13 *Charles-street, Berkeley-square.*
1840. May 7.		† Sharp, William, Esq., F.G.S. F.R.A.S. *Humber-bank-house, Hull.*

Date of Election.			
1839. May 9.			Sharpey, William, M.D. F.R.S.E. Professor of Anatomy in University-college. 35 *Gloucester-crescent, Regent's-park.*
1831. Apr. 21.			Shee, Sir Martin Archer, Knt. President of the Royal Academy. 32 *Cavendish-square.*
1830. April 1.			Sheepshanks, Rev. Richard, M.A. F.G.S. F.R.A.S. 14 *London-road, Reading.*
1824. Mar. 11.			Shuckburg, Sir Francis, Bart. *Pavilion, Hans-place, Chelsea; and Shuckburg-park, Warwickshire.*
1841. Mar. 4.		†	Sievier, Robert William, Esq. R.A. 12 *A, Henrietta-street, Cavendish-square.*
1845. Jan. 9.	P.		Simon, John, Esq., Demonstrator of Anatomy, King's College. 11 *Wellington-street.*
1837. Apr. 20.	P.	†	Skey, Frederic Carpenter, Esq. 13 *Grosvenor-street.*
1820. Mar. 23.			Sleath, Rev. John, D.D. F.S.A. 4 *Hertford-street, May-fair.*
1841. June 10.			Smee, Alfred, Esq. 7 *Finsbury-circus.*
1824. May 14.			Smith, Lieut.-Col. Charles Hamilton, F.L.S. *Plymouth.*
1830. Dec. 23.			Smith, James, Esq., F.R.S.E. *Jordan-hill, near Glasgow.*
1837. June 1.			Smith, John T., Esq., Capt. Madras Engineers. *Madras.*
1840. Jan. 9.		†	Smith, Rev. John Pye, D.D. LL.D. F.G.S. Prof. Div. and President of the Protestant Dissenting College, Homerton. *Homerton, Middlesex.*
1803. May 10.			Smith, John Spenser, Esq., F.S.A. *Caen, Normandy.*
1819. Nov. 25.			Smith, Joseph, Esq., F.L.S. 1 *Field-court, Gray's-inn.*
1806. Feb. 13.			Smith, Sir William, Knt.
1841. Nov. 18.		†	Smith, Sir J. M. Frederic, Lieut. Colonel R.E. *Chatham.*
1826. June 15.	P.		Smyth, William Henry, Esq.—VICE-PRESIDENT.—Capt. R.N. K.S.F. D.C.L. Hon. M.R.I.A. F.S.A. Pres. R.A.S.—Instit. Reg. Sc. Paris. Corresp., Acadd. Sc. Neap., Panorm. et Flor., Socius, Corresp. Mem. National Inst. Washington and Naval Lyceum of New York. 2 *Cheyne-walk, Chelsea.*
1843. Jan. 19.		†	Solly, Edward, Esq., Professor of Chemistry, Horticultural Society, F.L.S. 38 *Bedford-row.*
1807. May 7.		*	Solly, Richard Horsman, Esq., M.A. F.S.A. F.L.S. F.G.S. 48 *Great Ormond-street.*
1812. May 14.	P.		Solly, Samuel, Esq., F.L.S. 48 *Upper Gower-street; and Poole, Dorset.*
1837. Jan. 19.		†	Solly, Samuel, Esq. 1 *St. Helen's-place, Bishopsgate-street.*
1823. May 29.			Solly, Samuel Reynolds, Esq., M.A. F.S.A. F.G.S. *Surge-hill, King's Langley Herts.*
1797. Mar. 9.			Somerset, Edward Adolphus, Duke of, K.G. D.C.L. F.S.A. F.L.S. *Park-lane.*
1817. Dec. 11.			Somerville, William, M.D. F.R.S.E. F.L.S. F.G.S. *Rome.*
1845. June 5.			Sopwith, Thomas, Esq., F.G.S. *Allenheads, Haydon-bridge, Northumberland.*
1821. Feb. 15.	C.P.		South, Sir James, Knt. F.R.S.E. Hon. M.R.I.A. F.L.S. F.R.A.S. Acad. Imp. Sc. Petrop. Socius.—Acad. Reg. Sc. Brux. Corresp. *The Observatory, Camden-hill, Kensington.*
1825. Apr. 14.			Southey, Henry Herbert, M.D. Coll. Reg. Med. Socius. 1 *Harley-street.*
1834. Apr. 10.		†	Spence, William, Esq., F.L.S. Soc. Linn. Holm. Soc. 18 *Lower Seymour-street.*
1844. Feb. 1.		†	Stanford, John Frederick, Esq., M.A. *Foley-house, Portland-place.*
1807. Jan. 8.		*	Stanhope, Philip Henry, Earl. *Chevening-place, Kent.*

Date of Election.		
1816. June 27.		Stanhope, John Spencer, Esq.
1830. Mar. 11.		Stanley, Edward, Esq. 23 *A, Brook-street.*
1790. Apr. 29.		Stanley, John Thomas, Lord, F.S.A. 40 *Dover-street, Piccadilly.*
1842. Mar. 3.		Stanley, Owen, Esq., Capt. R.N., in command of H.M. Surveying Ship Rattlesnake.
1803. Apr. 28.		Staunton, Sir George Thomas, Bart. D.C.L. F.S.A. F.L.S. 17 *Devonshire-street, Portland-place.*
1845. Apr. 3.		† Stebbing, Rev. Henry, D.D. F.R.B.S. *Residence, St. James's-chapel, Hampstead-road.*
1832. April 5.		† Stephens, Archibald John, Esq., M.A. 61 *Chancery-lane.*
1829. Jan. 15.		Steuart, John Robert, Esq., M.R.A.S.
1811. Nov. 21.		Stevenson, William Ford, Esq., F.S.A. *Grande-rue, Passy, near Paris.*
1838. May 3.		Stirling, Edward Hamilton, Esq. *Calcutta.*
1821. Jan. 18.		Stokes, Charles, Esq., F.S.A. F.L.S. F.G.S. F.R.A.S. 4 *Verulam-buildings, Gray's-inn.*
1810. June 7.		Stracey, Sir Edward, Bart. LL.D. *Rackheath-hall, Norfolk.*
1825. Feb. 3.		Strangford, Percy Clinton, Sydney, Viscount, G.C.B. G.C.H. D.C.L. F.S.A. 68 *Harley-street.*
1821. Mar. 8.		Strangways, Hon. William Thomas Horner Fox. 31 *Old Burlington-street; and Abbotsbury, Dorsetshire.*
1832. June 7.		† Stratford, William Samuel, Esq., Lieut. R.N. F.R.A.S. Superintendent of the Nautical Almanac. 6 *Notting-hill-square, Kensington.*
1796. Nov. 17.		Sumner, George Holme, Esq., F.S.A. *Hatchlands, Guildford, Surrey.*
1846. June 18.		Sutherland, Alexander John, Esq., M.D. Coll. Reg. Med. Socius, Senior Physician to St. Luke's Hospital, F.G.S. M.R.C.S. 1 *Parliament-street.*
1828. Mar. 13.		Sutherland, Alexander Robert, M.D. Coll. Reg. Med. Socius, F.G.S. 1 *Parliament-street; and Torquay.*
1820. Dec. 14.		Swainson, William, Esq., F.L.S. Soc. Hist. Nov.-Ebor. Socius.—Soc. Hist. Nat. Paris. Corresp. *New Zealand.*
1839. Mar. 14.		† Swanston, Clement Tudway, Esq., F.S.A. 51 *Chancery-lane.*
1818. Feb. 26.		Swinburne, Sir John Edward, Bart. F.S.A. 18 *Grosvenor-place.*
1834. Feb. 6.	P.	† Sykes, Lieut.-Colonel William Henry.—VICE-PRESIDENT.—Hon. M.R.I.A. F.G.S. M.R.A.S. 47 *Albion-street, Hyde-park.*
1839. Apr. 25.		† Sylvester, James Joseph, Esq., M.A. F.R.A.S. 26 *Lincoln's-inn-fields.*
1835. June 4.		† Symonds, Sir William, K.H. Capt. R.N. 4 *Somerset-place.*
1813. May 6.		Talbot, Charles Chetwynd, Earl, K.P. F.S.A. *Ingestrie-hall, near Stafford; and* 10 *Great George-street.*
1831. Mar. 17.		Talbot, Christopher Rice Mansel, Esq. *Margam, Glamorganshire.*
1831. Mar. 17.	Rm. R.P.	Talbot, William Henry Fox, Esq., F.L.S. *Lacock-abbey, near Chippenham.*
1835. Feb. 5.		† Tattam, Rev. Henry, D.D. M.A. M.R.S.L. *Bedford.*
1845. Nov. 20.		† Taylor, Alfred Swaine, Esq., Lecturer on Chemistry and Medical Jurisprudence at Guy's Hospital. 3 *Cambridge-place, Regent's-park.*
1825. May 5.		Taylor, John, Esq., Treas. G.S. F.L.S. *Sheffield-house, Church-street, Kensington.*
1842. Feb. 10.		Taylor, Thomas Glanville, Esq., F.R.A.S. Astronomer to the East India Company. *Madras.*
1836. Jan. 21.		† Taylor, Rev. William. 77 *Westbourne-terrace, Hyde-park.*

Date of Election.			
1834. June 5.			Teignmouth, Charles John, Lord, D.C.L. 19 *Portland-place.*
1833. Dec. 5.			Terry, Charles, Esq., F.S.A.
1845. June 19.			Thesiger, Sir Frederick, Knt. 11 *Bryanston-square; and* 2 *King's-bench-walk, Temple.*
1846. Jan. 22.		†	Thompson, Theophilus, M.D. 3 *Bedford-square.*
1828. Nov. 20.			Thompson, Lieut.-Colonel Thomas Perronet, M.A. *Eliot-vale, Blackheath.*
1821. Dec. 20.			Thomson, James, Esq., F.L.S. *Primrose, near Clitheroe.*
1811. Mar. 28.	P.		Thomson, Thomas, M.D., Regius Professor of Chemistry, Glasgow, Hon. M.R.I.A. F.R.S.E. F.L.S. F.G.S. *Glasgow.*
1810. June 7.			Thornton, Right Hon. Edward, G.C.B. *Wembury-house, Plymouth.*
1834. Apr. 10.		†	Thornton, Henry Sykes, Esq., M.A. *Battersea-rise, Surrey.*
1839. May 30.		†	Thorp, The Venerable Charles, D.D. Archdeacon of Durham and Warden of the University of Durham. *Durham.*
1841. Feb. 25.		†	Tierney, Rev. Mark Aloysius. *Arundel, Sussex.*
1835. April 2.			Tite, William, Esq., F.S.A. 25 *Upper Bedford-place, Russell-square.*
1838. Feb. 8.		†	Todd, Robert Bentley, M.D. Coll. Reg. Med. Socius, Professor of Physiology and General Anatomy, King's College, London. 3 *New-street, Spring-gardens.*
1821. Mar. 22.			Tooke, Thomas, Esq. 31 *Spring-gardens.*
1818. Mar. 12.			Tooke, William, Esq., M.R.S.L. 12 *Russell-square.*
1818. Dec. 17.		*	Torrens, Lieut.-Colonel Robert. *Reform Club, Pall-mall.*
1812. Dec. 17.		*	Towneley, Peregrine Edward, Esq., Trust. Brit. Mus. F.S.A. 7 *Park-street, Westminster; and Towneley-hall, near Burnley, Lancashire.*
1842. Nov. 17.			Towneley, Charles, Esq. 3 *Tilnay-street, Park-lane.*
1822. Nov. 7.			Townley, George, Esq. 5 *L, Albany.*
1842. Mar. 10.	P.		Toynbee, Joseph, Esq. 12 *Argyll-place.*
1823. May 29.			Traherne, Rev. John Montgomery, M.A. F.S.A. F.L.S. F.G.S. *St. Hilary, near Cowbridge, Glamorganshire.*
1815. Nov. 16.			Travers, Benjamin, Esq. 12 *Bruton-street.*
1822. Nov. 14.			Tulk, Charles Augustus, Esq., F.S.A. *Totteridge-park, Herts.*
1843. May 18.			Tulloch, James, Esq., F.S.A. F.L.S. 16 *Montague-place, Bedford-square.*
1845. Apr. 10.		†	Tupper, Martin Farquhar, Esq., M.A. *Furze-hill, Brighton; and Albury, Surrey.*
1817. June 5.			Turnbull, Peter Evan, Esq., F.S.A. *Newport, Isle of Wight.*
1831. Mar. 17.			Turnbull, Rev. Thomas Smith, M.A. F.G.S. *Caius College, Cambridge.*
1821. May 24.			Turner, Charles Hampden, Esq., F.L.S. F.G.S. 15 *Bruton-street; and Rook's-nest-park, Godstone, Surrey.*
1802. Dec. 9.			Turner, Dawson, Esq., Hon. M.R.I.A. F.S.A. F.L.S. M.R.S.L. Acadd. Cæs. Nat. Cur. et Reg. Sc. Holm. Socius. *Athenæum Club; and Yarmouth.*
1815. Dec. 21.			Turner, Samuel, Esq. *Liverpool.*
1839. May 9.	P.	†	Turnor, Rev. Charles, M.A. F.S.A. F.R.A.S. *Cheltenham.*
1838. April 5.		†	Tuson, Edward William, Esq., F.L.S. *Harley-street.*
1838. Feb. 8.		†	Tweedie, Alexander, M.D. Coll. Reg. Med. Socius. 30 *Montague-place, Bedford-square.*
1834. June 5.			Twining, Richard, Esq. 13 *Bedford-place, Russell-square.*
1838. Mar. 15.		†	Twiss, Travers, Esq., D.C.L. F.G.S. Professor of Political Economy in the University of Oxford. 5 *B, Albany, Piccadilly.*
1820. Apr. 13.			Tylden, Lieut.-Colonel Sir John Maxwell, Knt. *Milsted, Kent.*

Date of Election.			
1821. Dec. 13.	P.		Ure, Andrew, M.D. F.R.A.S. 13 *Charlotte-street, Bedford-square.*
1813. June 24.			Vaughan, William, Esq. 70 *Fenchurch-street.*
1830. May 6.			Vetch, Capt. James, R.E. F.G.S. Corresp. Mem. Natt. Inst. Washington, U.S. *Truro.*
1823. Jan. 9.			Vivian, John Henry, Esq., F.G.S. 2 *Upper Belgrave-square; and Swansea, Glamorganshire.*
1826. June 8.			Vyvyan, Sir Richard Rawlinson, Bart. *Trelowarren, Cornwall.*
1828. Apr. 17.	P.		Walker, James, Esq., F.R.S.E. 23 *Great George-street, Westminster.*
1831. Mar. 3.			Walker, Rev. Robert, M.A. Reader in Experimental Philosophy in the University of Oxford. *Wadham College, Oxford.*
1830. April 1.			Wall, Charles Baring, Esq., M.A. F.S.A. M.R.S.L. 44 *Berkeley-square; and Norman-court, near Stockbridge, Hampshire.*
1829. Mar. 12			Wallich, Nathaniel, M. et Ph. D. F.R.S.E. F.L.S. F.G.S. M.R.A.S. Instit. Reg. Sc. Paris., et Acad. Reg. Sc. Berolin., Corresp.—Soc. Reg. Sc. Hafn. Socius. 5 *Upper Gower-street, Bedford-square.*
1819. Nov. 11.			Walter, Rev. Henry, B.D. *Hasilbury Brian, Dorsetshire.*
1837. May 25.		†	Walton, Rev. William, M.A. *Allenheads, Northumberland.*
1809. Feb. 16.			Warburton, Henry, Esq., M.A. 45 *Cadogan-place, Sloane-street.*
1817. May 1.			Warre, John Ashley, Esq. 54 *Lowndes-square, Sloane-street.*
1830. Dec. 9.	P.		Warren, Rev. John, M.A. *Graveley, Cambridgeshire.*
1835. April 2.		†	Warren, Samuel, Esq. *Inner Temple; and* 35 *Woburn-place.*
1815. June 8.			Warrender, Right Hon. Sir George, Bart. F.R.S.E.
1845. Feb. 13.		†	Washington, John, Esq., Capt. R.N. F.G.S. M.R.G.S. A.I.C.E. 24 *Chester-terrace, Regent's-park.*
1834. Feb. 6.			Waterhouse, John, jun., Esq. *Halifax, Yorkshire.*
1818. Nov. 12.			Watson, Sir Frederick Beilby, K.C.H. F.S.A. 4 *Albany-terrace, New-road.*
1820. Dec. 7.			Watt, James, Esq. *Aston-hall, Birmingham.*
1827. May 24.		†	Wavell, Major-General Arthur Goodall, K.F. K.C.S.
1826. Mar. 9.	P.		Weaver, Thomas, Esq., M.R.I.A. F.G.S. 16 *Stafford-row, Pimlico; and Woodlands, Wrington.*
1822. Mar. 21.			Webb, Frederick, Esq., F.S.A.
1844. Mar. 7.			Webster, John, M.D. Coll. Reg. Med. Socius. 24 *Brook-street, Grosvenor-square.*
1846. Feb. 19.		†	West, William, Esq. *Highfield-house, Leeds.*
1837. May 25.		†	Westmacott, Richard, Esq., F.G.S. 21 *Wilton-place, Belgrave-square.*
1814. June 9.			Weyland, John, Esq. 52 *Charles-street, Berkeley-square; and Woodrising-hall, Norfolk.*
1829. June 4.			Wharncliffe, Lord, B.A. *Wortley-hall, Sheffield; and Belmont-castle, Dundee.*
1840. Jan. 9.			Whatman, James, jun., Esq. *Vinters, near Maidstone, Kent.*
1836. Jan. 21.	R.P.	†	Wheatstone, Charles, Esq., Professor of Experimental Philosophy, King's College, London, Instit. Reg. Sc. Paris. Corresp. 20 *Conduit-street.*
1820. Apr. 13.	R.P.		Whewell, Rev. William, B.D. Hon. M.R.I.A. F.S.A. F.G.S. F.R.A.S. Master of Trinity College, Cambridge. *Lodge, Cambridge.*
1837. Apr. 13.		†	White, William Archibald Armstrong, Esq., F.S.A. 14 *College-street, Westminster.*
1842. Dec. 22.		†	Widdrington, Samuel E., Esq., Capt. R.N. *Newton-hall, Felton, Northumberland.*
1835. April 2.		†	Wigram, Hon. Sir James, Knt. M.A. F.S.A. 68 *Portland-place.*
1821. Mar. 8.			Wilbraham, George, Esq. *Delamere-house, Northwich, Cheshire.*

Date of Election.			
1834. Dec. 18.			Wilkinson, Sir John Gardner, Knt. 34 *Conduit-street.*
1835. April 2.		†	Williams, Charles James Blasius, M.D. Coll. Reg. Med. Socius, Professor of Physic in University College, London. 7 *Holles-street, Cavendish-square.*
1828. Mar. 6.			Williams, John, jun., Esq., F.L.S. *Scorrier-house, near Redruth, Cornwall.*
1830. Apr. 22.			Willis, Rev. Robert, M.A. F.G.S. Jacksonian Professor of Natural and Experimental Philosophy. *Cambridge.*
1812. May 7.			Wilmot, Sir John Eardley Eardley, Bart. D.C.L. F.S.A. F.L.S.
1838. Mar. 1.		†	Wilson, Alexander, Esq. 34 *Bryanston-square.*
1845. Feb. 6.	P.		Wilson, Erasmus, Esq., Lecturer on Anatomy and Physiology, Middlesex Hospital. 55 *Upper Charlotte-street, Fitzroy-square.*
1801. Apr. 16.			Wilson, Sir Giffin, Knt. 2 *Stratford-place; and Woburn-house, Beaconsfield, Buckinghamshire.*
1796. Apr. 28.			Wilson, Glocester, Esq. *Hastings.*
1834. Apr. 10.			Wilson, Horace Hayman, Esq., M.A. M.R.A.S. Boden Professor of Sanscrit in the University of Oxford. 14 *Upper Wimpole-street.*
1846. Feb. 19.		†	Wilson, John, M.D. *Greenwich.*
1845. Feb. 6.		†	Wilson, Rev. John, D.D. M.R.A.S. Hon. Pres. Bombay Branch of the R.A.S. *Bombay; and* 10 *Danube-street, Edinburgh.*
1834. June 5.			Witt, George, M.D. *Bedford.*
1813. Feb. 25.			Wix, Rev. Samuel, M.A. F.S.A. *Rectory-house, St. Bartholomew's the Less.*
1810. July 12.			Wix, William, Esq. *Tunbridge-wells, Kent.*
1829. Feb. 26.			Wollaston, Alexander Luard, Esq., M.B. F.R.A.S.
1812. Dec. 24.		*	Wood, William, Esq., F.L.S. *Ruislip, near Uxbridge.*
1836. Dec. 22.		†	Wood, William Page, Esq. 3 *Stone-buildings, Lincoln's-inn.*
1841. May 20.		†	Wood, Lieut.-Colonel Thomas. 26 *Hyde Park-gardens.*
1841. Apr. 29.		†	Woodward, Charles, Esq. 10 *Compton-terrace, Islington.*
1843. June 1.		†	Wright, Rev. John, M.A. F.S.A. F.R.A.S. M.R.S.L. 67 *Westbourne-terrace, Hyde-park-gardens; and The Vicarage, Malvern.*
1841. Apr. 29.		†	Wrottesley, John, Lord. *Wrottesley-hall, Wolverhampton.*
1839. Jan. 31.		†	Yates, James, Esq., M.A. F.L.S. F.G.S. 49 *Upper Bedford-place; and Norton-hall, Derbyshire.*

FOREIGN MEMBERS.

	Louis Agassiz	*Neufchatel.*	1838.
	François-Jean-Dominique Arago	*Paris.*	1818.
	F. G. A. Argelander	*Bonn.*	1846.
	Elie de Beaumont	*Paris.*	1835.
	Antoine César Becquerel	*Paris.*	1837.
	Jens Jacob Berzelius	*Stockholm.*	1813.
	Jean-Baptiste Biot	*Paris.*	1815.
	H. M. Ducrotay de Blainville	*Paris.*	1832.
	Alexandre Brongniart	*Paris.*	1815.
	Baron Leopold von Buch	*Berlin.*	1828.
	Francesco Carlini	*Milan.*	1832.
	Augustin-Louis Cauchy	*Paris.*	1832.
	Michel-Eugène Chevreul	*Paris.*	1826.
	Auguste De la Rive	*Geneva.*	1846.
	Jean-Baptiste Dumas	*Paris.*	1840.
	Christian Gottfried Ehrenberg	*Berlin.*	1837.
	Johann Franz Encke	*Berlin.*	1825.
	Paul Erman	*Berlin.*	1827.
	P. Flourens	*Paris.*	1835.
	Karl Friedrich Gauss	*Göttingen.*	1804.
	P. A. Hansen	*Seeberg.*	1835.
	Christopher Hansteen	*Christiana.*	1839.
	Baron Alexander von Humboldt	*Berlin.*	1815.
	C. G. J. Jacobi	*Königsberg.*	1833.
	A. T. Kupffer	*St. Petersburgh.*	1846.
C.	Baron von Liebig	*Giessen.*	1840.
	Baron von Lindenau	*Dresden.*	1833.
	Henry Frederic Link	*Berlin.*	1842.
	Joseph-Louis Gay-Lussac	*Paris.*	1815.
	Carl. Fried. Philip von Martius	*Munich.*	1838.
Rm.	Macédonie Melloni	*Parma.*	1839.
	C. F. Brisseau Mirbel	*Paris.*	1837.
R.	Eilert Mitscherlich	*Berlin.*	1828.
	Johann Müller	*Berlin.*	1840.
C.	Jens Christian Oersted	*Copenhagen.*	1821.
C.	George Simon Ohm	*Nuremberg.*	1842.
C.	Baron Giovanni Plana	*Turin.*	1827.
	Jean Victor Poncelet	*Paris.*	1842.
	G. de Pontécoulant	*Paris.*	1833.
	Lambert Adol. Jacques Quételet	*Brussels.*	1839.
	Henry Rose	*Berlin.*	1842.
	O. A. Rosenberger	*Halle.*	1835.
P.	Heinrich Christian Schumacher	*Altona.*	1821.
R.	Friedrich Georg Wilhelm Struve	*Dorpat.*	1827.
C.	Jacques Charles François Sturm	*Paris.*	1840.
	Le baron Thénard	*Paris.*	1824.
	Friedrich Tiedemann	*Heidelberg.*	1832.